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TENDON TRANSFERS AND ARTHRODESES IN COMBINED MEDIAN AND ULNAR NERVE PARALYSIS *

BY J. WILLIAM LITTLER, M.D., NEW YORK, N. Y.

The importance of the intrinsic muscles in relation to hand function becomes apparent following a lesion of both the median and ulnar nerves. A common injury may involve these two nerves in the brachium or at the wrist, where they are closely related. The functional loss is great and compensation is difficult. Excellent extrinsic-muscle function and good sensation may return after nerve suture, but the hand frequently is clawed and rendered almost useless through the loss of thumb opposition and finger extension (Figs. 1-A and 1-B). The pulp atrophy which often accompanies nerve injury is a severe disability and makes the already impaired pinch mechanism ineffectual.

This deformity can be overcome partially by appropriate tendon transfers and arthrodeses, designed to restore muscle balance and to bring the thumb and fingers into a functional position. An effort has been made to simplify the transfer of the tendons, as it is impossible to compensate for all the complex intrinsic-muscle functions. Frequently there is a dearth of transferable tendons, so that only the most important intrinsic functions can be considered. Successful transfers depend upon adequate strength and amplitude in the tendons, proper mechanics, good joint mobility, and freedom of the tissues from cicatrix.

The maintenance of a mobile hand, free from contracture, demands persistent effort during the period of nerve regeneration and prior to transfer of the tendons. Frequently the blood supply to the hand has been impaired, resulting in pain and stiffness. If a sympathetic-nerve block improves the circulation, a dorsal sympathetic neurectomy may be indicated. Repeated joint exercises through the complete normal range, coupled with dynamic splinting to maintain the hand in a good position, will greatly enhance the final functional result. Special effort must be made to prevent an adduction contracture of the thumb, a fixed hyperextension deformity of the metacarpophalangeal joints secondary to contracted collateral ligaments, and flexion deformities of the interphalangeal joints (Figs. 2-A, 2-B, and 2-C). Excision of the collateral ligaments in an effort to gain metacarpophalangeal flexion when interosseous-muscle paralysis is present may further cripple the hand by provoking the development of a marked ulnar deviation of the fingers. By leaving intact the collateral ligament on the radial side of the joint, enough relaxation can often be obtained to permit flexion without undue loss of stability. If the procedure is adopted, great care must be exercised to prevent damage to the extensor hood, which serves primarily to hold the extensor tendon in place over the apex of the metacarpophalangeal joint.

Opposition can be restored to a mobile thumb by prolongation of any active wrist flexor or extensor tendon with a free graft, or by the use of a finger flexor of sufficient length so that it pulls from an insertion on the medial aspect of the proximal phalanx of the thumb, over the lateral aspect of the metacarpophalangeal joint toward the pisiform, superficial to the palmar fascia (Fig. 3). The Bunnell silk technique is used between

* Read before the American Society for Surgery of the Hand, Chicago, Illinois, January 23, 1948.

FIG. 1-A FIG. 1-B

Complete paralysis of intrinsic muscles, showing typical deformity. The atrophy, muscle imbalance, and loss of thumb opposition are clearly demonstrated by the flattening of the palm, external rotation of the thumb, and hyperextension of the metacarpophalangeal joints of the fingers. Here the action of the long extensors and flexors is unopposed, and tendon transfers are necessary to restore balance and opposition. Good sensation and extrinsic-muscle function were gained through nerve suture in the brachium.

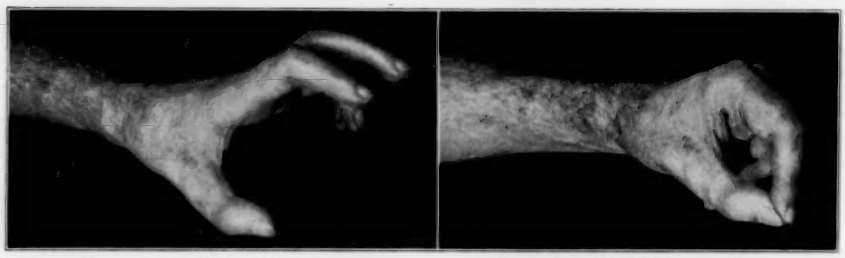

FIG. 1-C FIG. 1-D

A useful hand resulted through the restoration of thumb opposition and stabilization of the metacarpophalangeal joints.

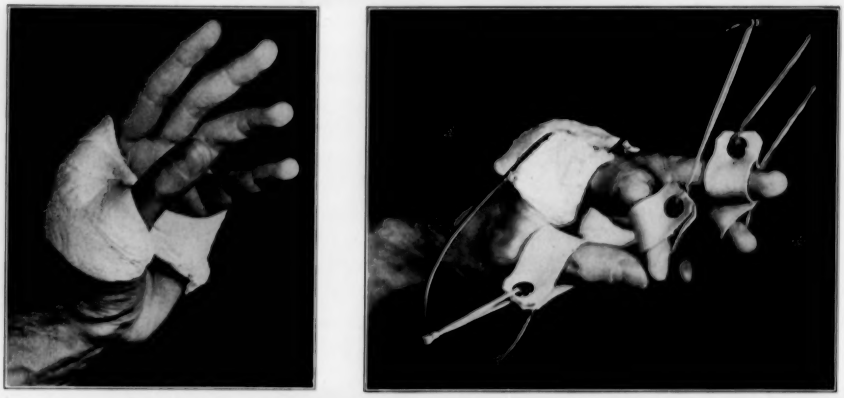

FIG. 2-A FIG. 2-B

Fig. 2-A: Basic splint designed to maintain the functional position of the hand and to prevent deformity in paralysis of the intrinsic muscles. The metacarpal arch is well developed, the metacarpophalangeal joints are prevented from hyperextending, and the thumb is held abducted at a right angle to the palm in the functional position. With hyperextension checked, the intact long extensors can act to extend the middle and distal phalanges.

Fig. 2-B: Basic splint with traction apparatus for correcting the adducted thumb and flexion contractures of the interphalangeal joints.

the graft and the transferred tendon, and his removable steel-wire technique is used at the insertion. If an extensor tendon is used, the free graft is passed subcutaneously around

the ulnar aspect of the hand. When the flexor carpi ulnaris is used, it is prolonged to the thumb with a free graft through a loose pulley at the pisiform. A finger flexor, if available, is excellent for motor power; and, when opposition has been lost through a local or low median-nerve injury, the procedure of choice is a transfer to the thumb of the normally functioning sublimis tendon of the ring finger, the flexor carpi ulnaris tendon being utilized as a pulley.

The abductor pollicis brevis alone is able to produce excellent opposition of the thumb, and it is the most important muscle of the thenar group[5,6]. By virtue of its insertion into the base of the proximal phalanx and into the long extensor, this muscle can stabilize the metacarpophalangeal joint in abduction, flexion, and pronation, and can assist extension of the terminal phalanx,—the essential functional components of opposition. Good results have been obtained by suturing the transferred tendon to the tendinous insertion of the paralyzed abductor pollicis brevis. The transfer is simplified and the correct insertion is assured.

If a wrist fusion is a desirable part of the reconstructive program, the opponens transfer should precede it, so that relaxation of the transferred tendon by wrist flexion can be obtained. When splinting has failed to correct an adduction contracture of the thumb and opposition is to be restored, the first metacarpal can be mobilized by excision of the contracted first dorsal interosseus, the flexor pollicis brevis, the adductor pollicis muscles, and the fascia. However, if this is done, a fusion of the metacarpophalangeal joint at 20 degrees of flexion or an adductor-tendon transfer may be necessary for stabilization.

The extensor pollicis longus is a direct antagonist to opposition, and in many cases the tendon is adherent

FIG. 2-C

Correction of fixed hyperextension deformity of metacarpophalangeal joints by elastic traction. The pull is maintained at right angles to the proximal phalanges from a point overlying the proximal interphalangeal joints. Wrist extension prevents forward slipping of splint and interference of palmar bar with flexion of metacarpophalangeal joint. Thumb traction is not shown. The pull is directed toward the tubercle of the navicular.

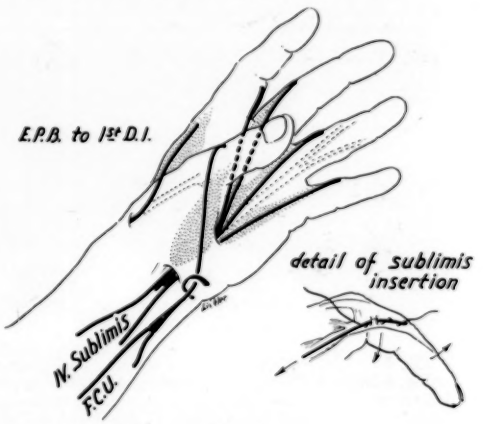

FIG. 3

Essential tendon transfers to restore opposition and the balance between the finger extensors and the intrinsic muscles in median and ulnar nerve paralysis. Shaded areas represent intrinsic muscles, compensated for by transfers. In some cases it is necessary to stabilize in flexion for a hyperextension deformity of the thumb metacarpophalangeal joint. A sublimis tendon is severed at the proximal interphalangeal joint, withdrawn at the wrist, and split into four divisions. Through a dorsolateral finger incision, the dorsal aponeurosis and lateral band are exposed; and a probe is passed along the lumbrical canal and tendon sheath to the wrist, where the sublimis divisions are caught, withdrawn, and sutured. Various muscles are used for power, but the principles of the transfers are unaltered.

E.P.B. to 1st D.I. = extensor pollicis brevis to first dorsal interosseus.

IV Sublimis = extensor digitorum sublimis to fourth digit.

F.C.U. = flexor carpi ulnaris.

FIG. 4-A

FIG. 4-B

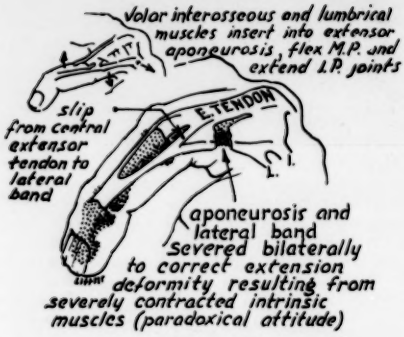
Volar interosseous and lumbrical muscles insert into extensor aponeurosis, flex M.P. and extend I.P. joints
slip from central extensor tendon to lateral band
EXTENSOR
aponeurosis and lateral band severed bilaterally to correct extension deformity resulting from severely contracted intrinsic muscles (paradoxical attitude)

FIG. 4-C

Fig. 4-A: Moderate ischaemic contracture of paralyzed intrinsic muscles prevents hyperextension of metacarpophalangeal joints and enables the long extensors to extend the interphalangeal joints.

Fig. 4-B: Full flexion is prevented by the tight dorsal-extensor mechanism.

Fig. 4-C: When the dorsal-extensor mechanism is so contracted that flexion is greatly impaired, the lateral bands and dorsal aponeurosis can be severed, as shown, through a dorsal mid-line incision over the proximal phalanx. This procedure releases the intrinsic-extensor function, but retains its flexor action at the metacarpophalangeal joint, thus permitting the long extensor to act on the interphalangeal joints.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Restoration of function of first dorsal interosseus by transference of extensor pollicis brevis.
Fig. 5-B: Opposition gained by prolonging flexor carpi ulnaris with palmaris longus graft. Lumbricalis interrosseous function has been restored by four-way splitting of ring-finger sublimis tendon and transference to dorsal aponeurosis, as illustrated in Fig. 3.

within its fibrous sheath at the wrist. In such cases the sheath must be opened and the tendon displaced to the radial side of the wrist, into the subcutaneous tissue. The transfer for opposition can then be done. A splint should be worn until the transferred tendon has gained sufficient strength and amplitude to maintain the thumb in the functional position.

In most hands the middle and terminal phalanges can be extended by the long extensor tendons, if hyperextension of the metacarpophalangeal joints is prevented [7]. This function is lost when the intrinsic muscles which stabilize the joints are paralyzed. A moderate contracture of the paralyzed lumbricalis interosseous muscles favors hand function in combined median and ulnar nerve injury by stabilizing the metacarpophalangeal joints in partial flexion or by preventing their hyperextension, so that the intact long extensors can act to extend the interphalangeal joints (Figs. 4-A, 4-B, and 4-C). This paradoxical function is simulated by tendon transfers, which serve as a checkrein on exten-

FIG. 6-A

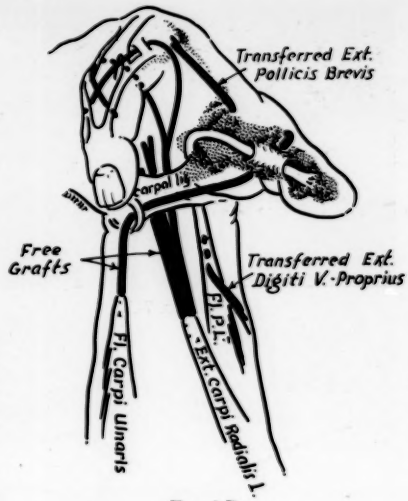

FIG. 6-B

Fig. 6-A: Intrinsic-muscle paralysis with complete loss of proximal and distal interphalangeal-joint extension. Weakened long extensors had no effect on the middle phalanges when the metacarpophalangeal joints were held in flexion.

Fig. 6-B: Opposition was restored by prolongation of the flexor carpi ulnaris with a free graft. Finger extension was gained by prolongation of the detached extensor carpi radialis longus with free tendon grafts (toe extensors) to the dorsal aponeurosis and lateral bands of the fingers, as shown in the sketch. This transferred tendon primarily flexes the metacarpophalangeal joint; but coordinately, when metacarpophalangeal-joint flexion is prevented by the long extensor, the force of the transfer is then exerted toward interphalangeal-joint extension. The wrist had to be fused for stability. Abduction of the index finger was provided by transference of the extensor pollicis brevis to the tendinous insertion of the first dorsal interosseus; and thumb flexion, by a transfer of the main extensor of the little finger to the long flexor of the thumb.

FIG. 6-C

FIG. 6-D

Final views showing extension and opposition. A strong, useful hand resulted.

sion of the metacarpophalangeal joints. Restoration of the lumbricalis interosseous action, metacarpophalangeal-joint flexion, or stabilization and extension of the terminal phalanx of the finger, is gained by splitting into four strands a detached sublimis tendon from either the index finger, middle finger, or ring finger. These strands are passed from the wrist through the lumbrical canals [8] to the dorsal aponeurosis and lateral bands of the fingers, where, with the wrist and metacarpophalangeal joints flexed, they are secured with a running suture of stainless-steel wire (Fig. 3). Both the tendon and the aponeurosis are roughened to ensure union. This technique has been fully described by Bunnell.

Abduction of the index finger is restored by a transfer of the extensor pollicis brevis, if well developed, to the tendinous insertion of the paralyzed first dorsal interosseus [1] (Figs. 5-A and 5-B). (It would be unwise to sacrifice a sublimis tendon for this transfer [5].) In most cases this transfer is combined with the transfer of the sublimis to the dorsal aponeurosis. In the case of the index finger, when the abductor transfer is done, the sublimis strand is not passed through the lumbrical canal, but is sutured to the lateral band on the ulnar side, where it serves to adduct and flex the metacarpophalangeal joint and to assist in terminal extension (Fig. 3). The lateral band on the radial side of the index finger is composed chiefly of the small lumbrical tendon, whereas on the ulnar side it

FIG. 7-A

Fig. 7-A: Marked hyperextension of the metacarpophalangeal joint of the thumb, secondary to paralysis of the ulnar innervated intrinsic muscles. The palmar injury had destroyed the motor branch of the ulnar nerve. Loss of ring-finger extension was restored by suturing the severed common extensor tendon to the adjacent intact extensor of the middle finger.

Fig. 7-B: The detached ring-finger sublimis tendon was withdrawn through a palmar incision and was passed transversely beneath the flexor tendons to the insertion of the adductor pollicis muscle.

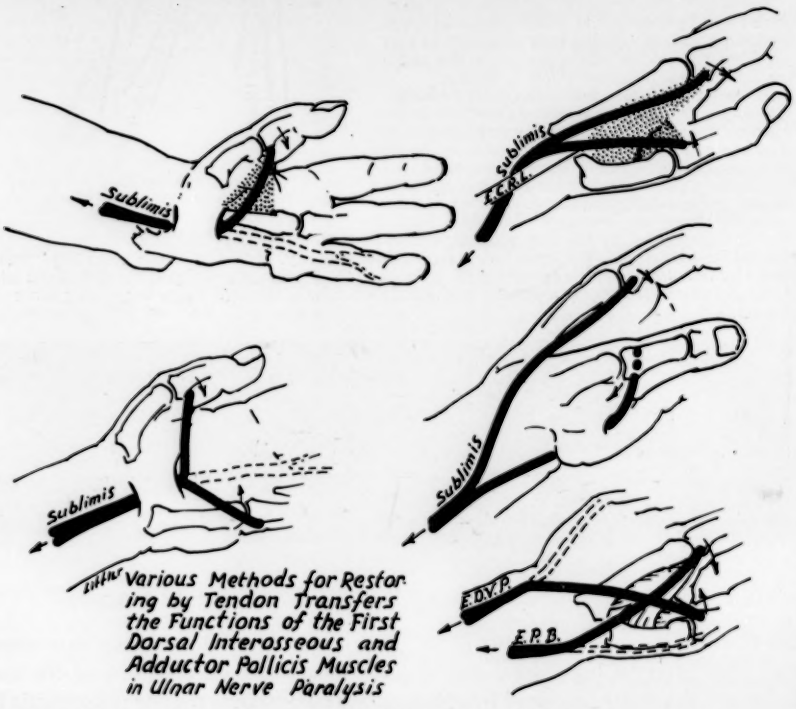

FIG. 7-B

E.C.R.L. = extensor carpi radialis longus.
E.D.V.P. = extensor digiti quinti proprius. *E.P.B.* = extensor pollicis brevis.

FIG. 7-C FIG. 7-D

The final photographs show the functional restoration with good metacarpophalangeal stability.

is formed by the strong volar interosseous tendon[9] and makes a better and more direct attachment for the transferred sublimis.

A wrist flexor or extensor tendon can be prolonged with four free grafts to the extensor aponeurosis, if finger strength would be jeopardized by the use of a sublimis tendon; or a paralyzed sublimis can be used by empowering it with an intact extensor tendon. Fowler has successfully utilized the main extensor tendons of the index finger and little finger for flexion of the metacarpophalangeal joint.

If the middle and terminal phalanges cannot be extended by the long extensors when the metacarpophalangeal joints are stabilized in mid-flexion, a tendon transfer from the volar aspect of the hand to the dorsal aponeurosis and lateral bands of the proximal phalanx will be ineffectual. The transferred

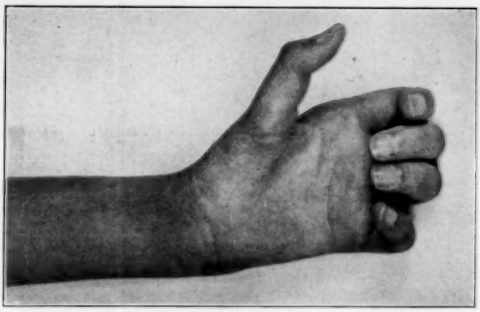

FIG. 8-A

Combined median and ulnar nerve paralysis, resulting from a wound involving the brachium. Nerve suture provided reactivation of forearm muscles with sensation, but no intrinsic-muscle function.

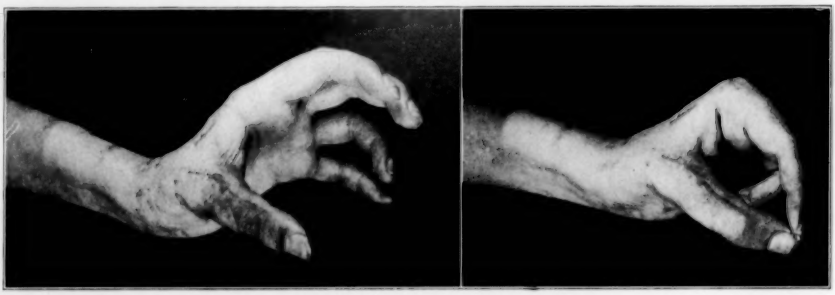

FIG. 8-B FIG. 8-C

Opposition was restored through the flexor carpi ulnaris and a free graft. The ring-finger sublimis was split and transferred to the dorsal aponeurosis of each finger. Fusion of the metacarpophalangeal joint of the thumb provided stability and corrected the hyperextension. Good finger extension, grasp, and pinch were restored.

FIG. 9-A FIG. 9-B

Fig. 9-A: Combined median, ulnar, and radial nerve paralysis. Good flexion returned after nerve suture, but wrist fusion and transfer of the flexor carpi radialis to the extensor tendons of the thumb and fingers were necessary to compensate for the radial-nerve loss. A functionless and anaesthetic little finger was amputated. Acute flexion of the terminal phalanges, resulting from intrinsic-muscle paralysis and flexor imbalance, impaired function.

Fig. 9-B: By fusion of the distal joints of the thumb and index finger in the pinch position, a very useful hand was obtained.

FIG. 10-A

FIG. 10-B

Fig. 10-A: Total loss of flexor function and paralysis of intrinsic muscles resulted from a gross destructive wound of the forearm. The median and ulnar nerves were approximated and a fair degree of sensation was restored to the hand. A wrist fusion made active extensor tendons available for flexion of thumb and fingers, but the poor position of the thumb made the hand useless.

Fig. 10-B: By fusion of the carpometacarpal and the interphalangeal joints, a useful thumb in good position was obtained.

FIG. 11-A

Fig. 11-A: Permanent fixation of the first metacarpal in the position of optimum usefulness by an intermetacarpal strut of tibial bone.

Fig. 11-B: Sketch illustrating the architectural principles involved in placing the bone strut between the first and second metacarpals.

1: The first metacarpal is held at an angle of 90 degrees to the palmar plane, and may be rotated from 30 to 45 degrees on its longitudinal axis.

2: An angle of 45 degrees is obtained between the two metacarpals at the carpus.

3: Lateral placement of the strut rotates the first metacarpal.

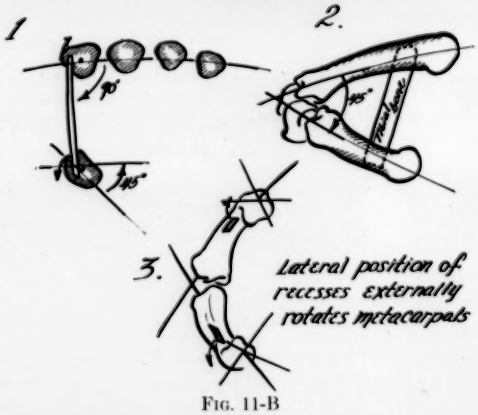

FIG. 11-B

tendon will have to be carried from each side of the finger over the dorsal apex of the proximal interphalangeal joint into the converging lateral bands of the middle phalanx, according to the method of Fowler (Figs. 6-A to 6-D). Full passive extension of the proximal interphalangeal joint is imperative, if the transfer is to be successful. A metal splint to hold the wrist and metacarpophalangeal joints flexed and the interphalangeal joints extended will greatly facilitate the suturing.

If an additional sublimis tendon can be spared, the palmar and thumb arches can be restored by suturing one division of the detached tendon to the adductor pollicis insertion and the other division to the base of the proximal phalanx of the little finger on its ulnar aspect; or the entire tendon may be sutured only to the adductor pollicis insertion. The former procedure simulates the tendon T operation described by Bunnell, and is used when both arches are to be restored; the latter procedure is used in patients having marked

hyperextension of the metacarpophalangeal joint of the thumb (Figs. 7-A to 7-D).

The arch of the thumb is maintained by the long abductor, the adductor, and short flexors, which prevent hyperextension of the metacarpophalangeal joint. If the joint is hyperextended when the adductor and flexor pollicis muscles are paralyzed, the terminal phalanx is pulled into flexion by the flexor pollicis longus (Froment's sign); and in time an irreversible flexion contracture of the interphalangeal joint may result, greatly impairing opposition. When the interphalangeal joint cannot be extended passively, or if the long thumb extensor cannot extend the terminal phalanx when the metacarpophalangeal joint is stabilized, a fusion of the interphalangeal joint at 15 to 30 degrees of flexion or extension (the latter only if pulp atrophy is severe) will permit useful opposition of the thumb to the fingers. When the interphalangeal joint has been fused, the flexor pollicis longus flexes the metacarpophalangeal joint. If the flexed terminal phalanx can be extended by the long extensor when the metacarpophalangeal joint is stabilized, and no tendon is available for transfer, a fusion of this joint at 20 degrees of flexion and 10 degrees of pronation will make possible active extension of the terminal phalanx and greatly improve opposition (Figs.

FIG. 12-A

Destruction of forearm muscles and of median and ulnar nerves resulted in total loss of useful hand function. Sensation was restored through nerve suture.

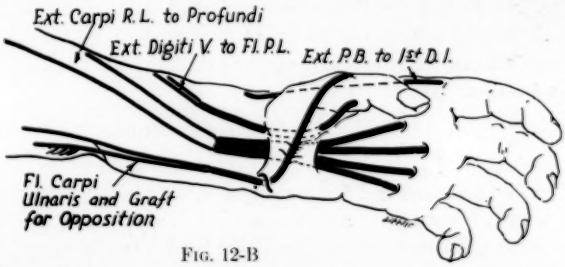

FIG. 12-B

Fig. 12-B: Finger flexion, thumb flexion and opposition, and index-finger abduction were restored by tendon transfers, as illustrated in sketch.

FIG. 12-C

Figs. 12-C, 12-D, and 12-E: Despite the loss of intrinsic-muscle function, the fingers fortunately did not claw and a good functional result was obtained.

FIG. 12-D

FIG. 12-E

8-A, 8-B, and 8-C). A tendon transfer for opposition may rotate the thumb metacarpal and the proximal phalanx into good position; but, if the terminal phalanx remains acutely flexed, pulp opposition is not attained (Figs. 9-A and 9-B).

Amputation through the interphalangeal joints of the thumb and fingers is sometimes necessary to eliminate the acutely flexed and atrophic terminal phalanges. This provides a fully rounded finger tip and eliminates the added complexity of interphalangeal function. When an adducted thumb cannot be mobilized sufficiently by a tendon transfer, a functional position can be obtained either by fusion of the carpometacarpal joint (Figs. 10-A and 10-B) or by bridging of the first intermetacarpal space with a bone graft (Figs. 11-A and 11-B). Temporary joint stabilizations are sometimes useful in maintaining good position until tendon transfers are functioning or until some deformity has been corrected. A Kirschner wire passed through a joint will maintain position for long periods of time; but, after removal, function will again be possible.

Volitional control of transferred tendons is readily gained if the innervation of their muscles is unimpaired. Paralyzed muscles which have regained function following nerve suture often lack the highly individualized control and strength desirable for successful transfers. It is frequently necessary, however, to use such a muscle for transfer in combined median and ulnar nerve injuries; but the results may be good, especially if only an automatic checkrein effect is required to prevent hyperextension of the metacarpophalangeal joints. The stretch reflex seems to have some bearing on the re-education of transferred tendons. Following the three-week period of immobilization after operation, the patient must be trained carefully in the use of the transfers. He must know what previous function has been altered, and his efforts must be directed toward volitional and synergistic control of the transferred tendons.

CONCLUSIONS

Residuals of a single-nerve injury, manifested by paralysis and muscle imbalance, are readily compensated for by appropriate tendon transfers. The procedure becomes complicated when any two nerves are involved. Correct evaluation of the partially paralyzed hand must be made and available tendon power must be concentrated where it will be effective in restoring useful function. Proper arthrodeses will provide stabilization and make additional power available for transfer. Not infrequently it is necessary to fuse the wrist or the thumb, or both, in a position of function, and to transfer wrist-extensor tendons, if a good pinch and grasping mechanism is to be gained. In badly crippled hands only a pinch mechanism may be possible, but to that end we should concentrate our effort; if we attempt more, potential power may be dissipated and a useless hand will result.

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SURGICAL APPROACHES TO THE SHOULDER JOINT *

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The shoulder joint is a complex mechanism consisting of the sternoclavicular, the acromioclavicular, and the scapulohumeral joints, together with the virtual joint between the scapula and the thoracic cage. Contrary to traditional teaching, elevation of the arm is accomplished by movement occurring simultaneously in the several joints, acting as a single unit to produce that smoothness of motion aptly termed "scapulohumeral rhythm". Operations upon any of the joints of the complex must be planned with the idea of minimum interference with their gliding surfaces and with the ligaments and muscles which support and control their movements. For example, ankylosis resulting from an operation on the acromioclavicular joint permanently disturbs the rhythm and reduces the range of motion in the shoulder as a whole. Therefore, there are two features which demand major consideration from the surgeon. The first of these is a realization of the functional and dynamic aspects of the shoulder complex. The second is an accurate anatomical knowledge which will enable him to carry out the contemplated procedure with the least possible disturbance of function. Although these joints operate as a unit, the surgical approaches to each one should be considered separately.

THE STERNOCLAVICULAR JOINT

Surgical Anatomy

The sternoclavicular joint is established by the articulation of the medial end of the clavicle with the clavicular notch of the manubrium sterni and the superior surface of the first costal cartilage. The bony surfaces of the articulation are separated by an intra-articular fibrocartilaginous disc; and the entire joint is isolated by a capsule, reinforced in front and behind by the anterior and posterior sternoclavicular ligaments, of which the posterior is by far the more substantial. The joint is strengthened by two accessory ligaments, the interclavicular and the costoclavicular. The interclavicular ligament is attached to the rough, upper portion of the medial end of the clavicle on each side, blends with the superior portion of the capsular ligament, and is adherent at its middle to the center of the suprasternal notch. The strong, short, costoclavicular ligament passes from the costochondral junction of the first rib to be attached to the tubercle on the inferior aspect of the clavicle, near its medial end (Fig. 1).

Functionally, the joint permits elevation and depression of the clavicle with the corresponding movements of the arm, forward and backward movements with retraction and protraction of the shoulder, as well as circumduction. In addition, the sternoclavicular joint, together with the acromioclavicular, permits rotation of the clavicle about its long axis during elevation of the extremity. All these movements, with the exception of the backward and forward motions, occur in the lateral compartment of the joint between the disc and the clavicle.

Two features of the joint are of special importance to the surgeon. First, it should be recognized that the integrity of the joint is dependent in greatest measure upon the accessory ligaments, notably the costoclavicular. Second, the relations of the joint, especially the intimacy of the great veins of the neck to the posterior aspect and the close relationship of the pleura, must be borne in mind. The first point is of significance in the

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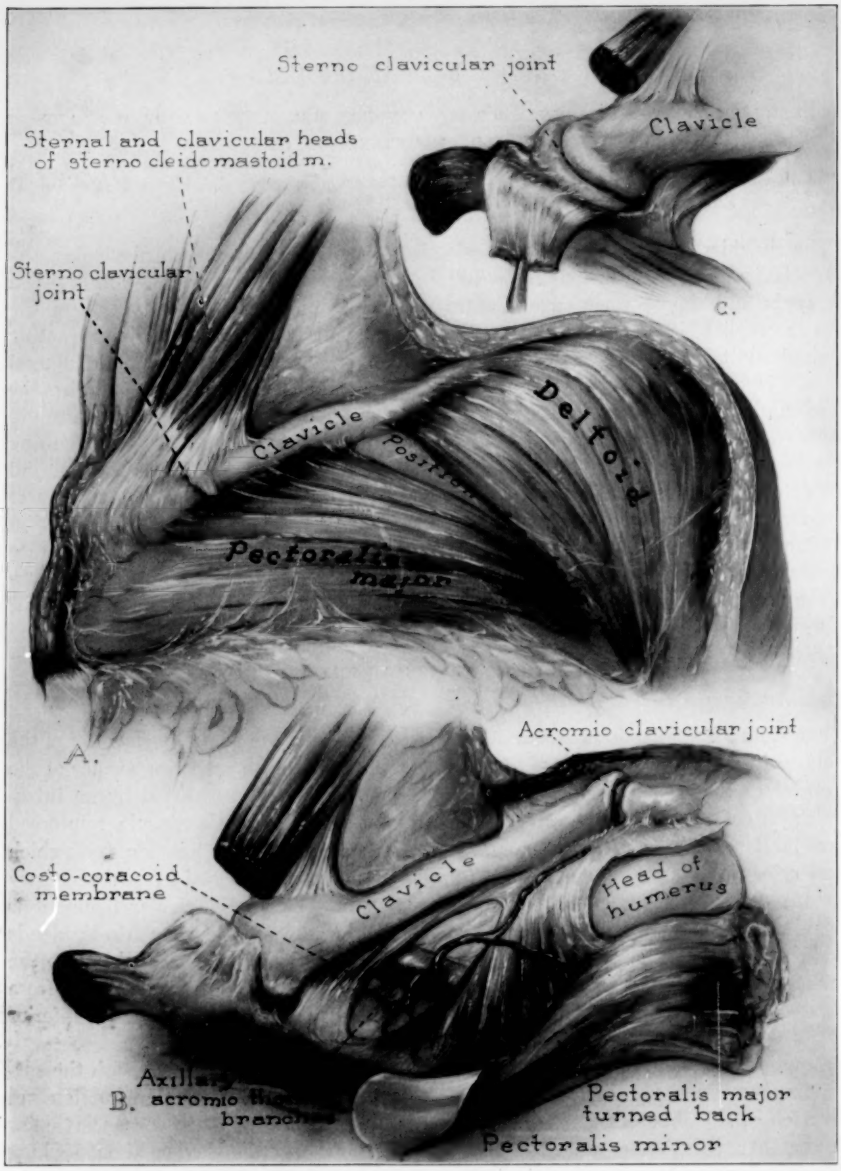

FIG. 1

Dissections to show anatomical relationship of the sternoclavicular and acromioclavicular joints.

A: The clavicle and the cephalic vein, lying between adjacent borders of the pectoralis major and deltoid; and the relationship of the sternoclavicular joint to the sternal and clavicular heads of the sternocleidomastoid.

B: The acromioclavicular joint, the pectoral muscles, and the costocoracoid membrane.

C: The sternoclavicular joint.

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mechanism of dislocation and establishes the principles for its repair, and the second constitutes hazards in operative approaches.

Therefore, the important structures on the anterior and superior aspects of this joint are the upper fibers of the pectoralis major, the sternal head of the sternocleidomastoid, and, in close proximity, the clavicular head of the same muscle with the anterior and external jugular veins disappearing beneath the medial and lateral borders of the muscle, respectively. Posterior to the medial inch of the clavicle are the attachments of the sternohyoid and sternothyroid muscles, which separate the bone from the innominate vein, phrenic nerve, internal mammary artery, pleura, and lung from before backward. The right joint is related posteriorly to the innominate artery, in addition. The left joint is in especially close relationship to the innominate vein,—so much so that the vein may be adherent to it and, with careless manipulations, there may be danger of damage to its walls, producing hemorrhage or thrombosis.

Approaches to the Sternoclavicular Joint

A. *Indications:* The indications are:
(1) recurrent and disabling dislocation of the joint;
(2) infection requiring drainage; and
(3) tumors involving the joint.

B. *Position of the Patient:* The patient is supine with a small sandbag placed between the shoulder blades.

C. *Incision:* A straight or curved incision is made through the skin, exposing the capsule of the joint and the two heads of the sternocleidomastoid. The joint surfaces are then exposed by curved division of the capsule and by subperiosteal reflection of the heads of the sternocleidomastoid. Through this approach the joint can be inspected thoroughly. When tumors involve this joint, a more extensive dissection may be required, with ligation of the anterior and external jugular veins.

THE ACROMIOCLAVICULAR JOINT

The acromioclavicular joint is the diarthrosis occurring between the lateral end of the clavicle and the anteromedial margin of the acromion (Fig. 1). The opposed articular surfaces lie in an oblique plane which passes downward and medially. The weak capsule, thickened above and below, contains a wedge-shaped articular disc which protrudes into the joint cavity from the upper portion of the capsule. The joint is strengthened by an accessory ligament, the coracoclavicular, which extends from the upper surface of the coracoid process to the inferior aspect of the lateral end of the clavicle. The coracoclavicular ligament consists of two portions: the trapezoid ligament, lying anterolaterally and attached to the trapezoid ridge of the clavicle; and the conoid ligament, placed posteromedially and affixed to the conoid tubercle at the apex or summit of the curvature in the lateral third of the clavicle. The interval between the two segments is occupied by a bursa, which lessens the friction between them during motion. The coracoclavicular ligament constitutes the important structural support of the acromioclavicular joint and, apart from muscles, the entire upper extremity is suspended from it. Dislocation of the acromioclavicular joint cannot occur without damage in greater or less degree to this accessory ligament, surgical repair of which is often necessary when the dislocation is complete.

Functionally, slight gliding movements in various directions are permitted at the acromioclavicular joint, which serve to maintain an unchanged relationship between the glenoid cavity of the scapula over the head of the humerus in all positions of the extremity. However, of far greater importance is the rotation of the clavicle about its long axis during elevation of the extremity. This rotation, amounting to approximately 45 degrees, enables the curved outer end of the clavicle to act as a crankshaft. Since the coracoclavicular ligament is attached to the apex of this crank, these structures undergo relative elongation during elevation which, in turn, permits the complete rotation of the scapula. Interruption

of this movement of clavicular rotation immediately limits active abduction to about 90 degrees, although the extremity can be carried passively to about 110 degrees. Furthermore, in reconstructing the coracoclavicular ligament by the fascia lata or other material, the new ligament should, in order to preserve the functional mechanism, be attached to the clavicle well posteriorly, at the apex of the lateral curve or along the trapezoid line. Otherwise, some restriction of motion can be anticipated.

Approaches to the Acromioclavicular Joint

A. *Indications:* The indications are:
(1) acromioclavicular dislocations;
(2) fractures involving the joint;
(3) infections; and
(4) arthritis.

B. *Position of the Patient:* The patient is in a sitting position, with the shoulder extending well beyond the edge of the table and with the arm at the side.

C. *Incision:* For repair of the coracoclavicular ligament, an extensive exposure is generally required, such as is described by Roberts. Beginning at the angle of the acromion, an incision is made over its lateral and anterior margins, thence across the acromioclavicular joint and along the anterior surface of the lateral one-third of the clavicle; from here it turns downward and outward to follow the groove between the pectoralis major and deltoid muscles. Here, the coracoid process is a valuable guide, since it lies one inch below the junction of the middle and lateral thirds of the clavicle, where it is covered by the inner margin of the deltoid. By the separation of the pectoralis major and deltoid, the cephalic vein is revealed as it passes obliquely upward and backward to pierce the costocoracoid membrane, where it joins the axillary vein. The vein should be preserved within its sheath, and retracted medially with a thin section of the deltoid. Following this, the origin of the deltoid is detached from the clavicle with a thin shaving of bone. This produces less bleeding than when a strictly subperiosteal detachment is made. In order to permit reflection of the origin of the deltoid laterally, the deltoid branches of the acromiothoracic axis are ligated. The coracoid process is then exposed, and on it may be seen the insertion of the pectoralis minor and the combined origin of the short head of the biceps and the coracobrachialis. The repair of the coracoclavicular ligament may be accomplished by any one of a variety of techniques, such as those employed by Bunnell, Bankart, or Lowman.

THE SCAPULOHUMERAL JOINT

Surgical Anatomy

The scapulohumeral joint is established by the articulation of the large hemispherical surface at the humeral head with the comparatively small and slightly concave surface of the glenoid cavity of the scapula. The glenoid is deepened and enlarged by the presence of the labrum glenoidale or so-called glenoid ligament, a ring of fibrocartilaginous tissue triangular in section, attached to the periphery of the cavity. The joint is strengthened above by the so-called "arch of the shoulder", formed by the coracoid process, the acromion, and the coraco-acromial ligament. The capsule, exceedingly lax, is attached proximally to the labrum and the rim of the glenoid cavity, blending directly above with the intra-articular attachment to the long head of the biceps; distally it encircles the head and is fused superiorly with the anatomical neck of the humerus, but inferomedially it extends on to the surgical neck, about half an inch below the head. The capsule is reinforced superiorly by the coracohumeral ligament, morphologically a continuation of the tendon of the pectoralis minor, and anteriorly by the three ill-defined glenohumeral ligaments. The anterior aspect of the capsule presents a deficiency of varying size, through which is herniated a portion of the synovial lining of the joint to establish the subscapularis bursa.

The long head of the biceps arises within the joint from the supraglenoid tubercle and blends with the labrum glenoidale. It traverses the joint, resting on the upper surface of the head of the humerus, to reach the intertubercular groove. The intra-articular portion of the tendon is surrounded by synovial membrane, which is carried by the tendon for some distance beyond the capsular attachment to form a second synovial herniation. The tendon is held in position by means of the transverse humeral ligament, an insignificant structure roofing the intertubercular groove. Maintenance of the tendon in its groove is dependent in large measure on the thickening of the lateral margin of the capsule, where it bridges the interval between the greater and lesser tubercles, and on the tendon of the pectoralis major, as it passes laterally to its insertion on the lateral lip of the groove. Consequently, dislocation of the tendon can occur only in the medial direction. Functionally, the humerus glides on the tendon during motion for a distance of almost an inch, and the synovial pouch permits this to occur without friction. The presence of an adhesive tendinitis, therefore, not only limits motion, but, by pulling upon adhesions, results in the production of pain.

The structures in immediate relationship to the joint are the short rotator muscles. Active support to the anterior aspect of the joint is afforded by the tendon of the subscapularis, inserted into the lesser tuberosity of the humerus and separated from the capsule by the subscapularis bursa. Superiorly is the tendon of the supraspinatus, and posteriorly the tendons of the infraspinatus and teres minor. These muscles insert, from before backward in the order named, into the greater tuberosity of the humerus. The inferior aspect of the joint is unsupported and lies in relationship to the so-called quadrilateral space. The tendons of the four muscles mentioned blend with one another as a musculotendinous cuff which, in a sense, constitutes a partial secondary capsule for the joint. Between the musculotendinous cuff and the capsule exists a small quantity of areolar tissue, which serves as a gliding plane during muscular activity. The great importance of the musculotendinous cuff in maintaining the integrity of the joint should be borne in mind constantly. Furthermore, these short muscles, especially those lying on the anterior and posterior aspects, constitute one of the essential components of the force couple, which is the essential mechanism for active elevation of the arm. The deltoid alone is incapable of abducting the humerus without the interaction of these small muscles.

The deltoid hangs like a curtain from the overlying acromial arch, covering the anterior, lateral, and posterior aspects of the joint. It arises from the lateral third of the clavicle, the lateral border of the acromion, and the inferior border of the spine of the scapula, to insert into the deltoid tubercle on the middle of the lateral border of the shaft of the humerus (Fig. 3). Four features of importance present themselves to the surgeon in connection with this muscle. First, the origin of the muscle extends for some distance on the superior aspect of the bones, from which it arises in the form of tendinous fibers. These fibers, by blending with the periosteum, permit surgical detachment of the muscular origin with a considerable border of connective tissue, which readily permits reattachment without undue tension on the sutures. Second, in close relationship to the muscle origin and beneath it lie a group of vessels following the origin circumferentially which, if sought for and ligated in the region of the anterior portion of the muscle, permit detachment with little or no hemorrhage. Third, the region of the muscle lying approximately opposite the tip of the acromion process presents a tendinous interval, an inch and a half to two inches in length, which enables the surgeon to split the muscle at this point through a relatively bloodless field. A fourth feature of importance is the precise relationship of the axillary nerve, which will be discussed later.

Beneath the deltoid lies the subdeltoid or subacromial bursa. This bursa is very extensive and not only lies between the deltoid muscle and the greater tubercle of the humerus, but extends beneath the acromial arch and the coraco-acromial ligament above the joint as far medially as the root of the coracoid process. In its floor, therefore, lie the

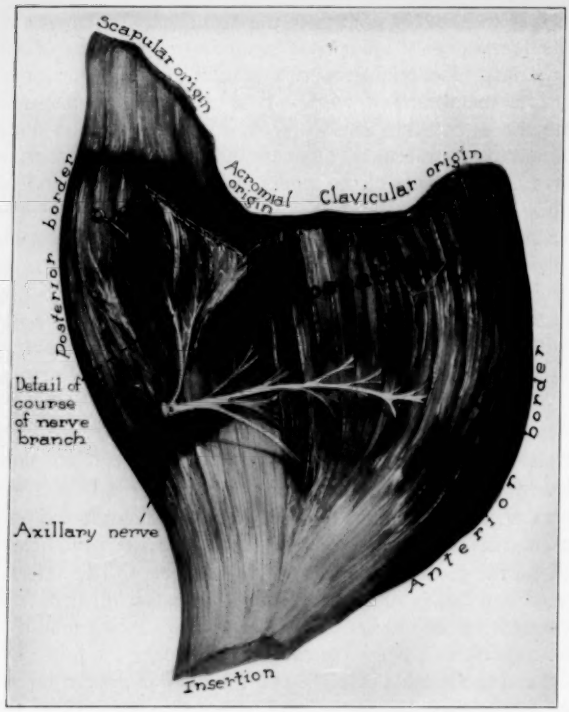

FIG. 2

Dissection of the inner aspect of the left deltoid, demonstrating the location of the axillary nerve. The course of the nerve lies about two inches below the origin of the muscle. Detail of one branch shows that muscle-splitting incisions, even in the operable area, do some damage to the innervation.

musculotendinous cuff, the tubercles of the humerus, and the intertubercular sulcus. An excellent description of the detailed arrangement of this bursa is to be found in Codman's book, *The Shoulder*.

The pectoralis major, arising from the medial portion of the clavicle, the anterior aspect of the sternum, the upper ribs, and the aponeurosis of the external oblique, is inserted by means of a flat, bilaminar tendon into the lateral lip of the intertubercular groove. The clavicular head passes anterior to the sternocostal head to insert more distally and blend with the tendinous insertion of the deltoid. The upper sternocostal fibers run under cover of the clavicular portion and fuse with the deep surface of its tendon. The lower sternocostal fibers and those arising from the aponeurosis curve upward behind the upper sternocostal fibers, to extend beyond their insertion as a fascial expansion, which stretches over the biceps tendon to blend with the capsule of the shoulder joint.

The cephalic vein lies in the deltopectoral groove, formed by the adjoining margins of the deltoid and pectoralis major, respectively. Here the vein is associated with tributaries from neighboring structures and, as it passes upward, it occupies a progressively deeper level, eventually piercing the costocoracoid membrane to join the axillary vein. The cephalic vein is, therefore, a useful guide to the axillary vessels.

Under cover of the anterior border of the deltoid lies the coracoid process, from which the coracobrachialis and short head of the biceps arise and into which the pectoralis minor is inserted. The former muscles, therefore, have a close anterior relationship with the joint, and the tendon of the pectoralis minor is frequently exposed in operative approaches. Medial to the coracobrachialis lie important branches of the brachial plexus and the great vessels; therefore, exploration on the medial side of this muscle should be undertaken with especial care.

Postero-inferiorly are the tendons of the latissimus dorsi and the teres major, forming the posterior wall of the axillary space. The tendon of the latissimus dorsi winds around that of the teres major to insert into the floor of the intertubercular groove, whereas the teres major inserts into its medial lip.

On the inferior aspect, bounded laterally by the shaft of the humerus, below by the teres major, medially by the long head of the triceps arising from the infraglenoid tubercle, and above by the subscapularis, capsule of the shoulder joint, and teres minor, is the

quadrilateral space, through which pass the axillary nerve and the posterior circumflex humeral artery.

The surgeon should recall the position of the transverse scapular artery and suprascapular nerve as they lie superomedial to the joint. The nerve passes through the suprascapular notch, medial to the coracoid process and the artery immediately above it. Both enter the supraspinous fossa and, having supplied the muscle contained therein, wind around the root of the spine through the greater scapular notch to reach the infraspinous fossa, terminating in the infraspinatus muscle. These structures are endangered in tears of the musculotendinous cuff, if the divided tendon is sought for too deeply and carelessly.

Nerves about the Shoulder

In surgical approaches to the shoulder joint, the axillary nerve occupies a position of supreme importance. It arises from the posterior cord of the brachial plexus, posterior to the great vessels; and, as it descends, it passes inferior to the capsule of the shoulder joint through the quadrilateral space. Here it divides into posterior and anterior divisions. The posterior division supplies motor branches to the teres minor and the posterior third of the deltoid muscle. From it is derived the lateral cutaneous nerve of the arm, which winds around the posterior border of the deltoid, accompanied by a small vessel to supply the skin over the upper lateral aspect of the deltoid. In posterior approaches, isolation of this small cutaneous nerve, readily recognized owing to the presence of the accompanying vessel, enables the surgeon, by following it more deeply, to recognize the main trunk of the nerve. The anterior division proceeds around the surgical neck of the humerus, accompanied by the posterior circumflex artery. In relationship to the surface, the nerve occupies a position a little above the mid-point between the lateral margin of the acromion process and the insertion of the deltoid. The anterior division supplies the anterior two thirds of the deltoid, and its protection is of the greatest importance in superolateral approaches to the joint. Its muscular twigs are given off at intervals, to pass vertically upward. Therefore, incisions which are made with separation of the fibers of the deltoid should not extend downward for more than one and one-half inches below the margin of the acromion process; otherwise some weakness of the deltoid can be anticipated (Figs. 2 and 3).

Other important nerves in this area are well described in standard textbooks. They are the suprascapular nerve to the supraspinatus and infraspinatus; the musculocutaneous nerve to the biceps, coracobrachialis, and brachialis; the lateral and medial anterior thoracic nerves to the pectoralis major and minor; the upper, middle, and lower subscapular nerves to the teres major, subscapularis, and latissimus dorsi; and the radial nerve to the triceps. All are derived from the cords of the brachial plexus, which surround the great vessels in the axilla.

Arteries

The arteries of importance in approaches to the shoulder are the transverse scapular, derived from the thyrocervical trunk; and branches from the axillary artery,—namely, the thoraco-acromial and the anterior and posterior circumflex humeral vessels. The transverse scapular artery arises from the thyrocervical artery at the base of the neck and passes directly laterally. We are concerned with it only as it passes above the suprascapular notch, lying in close relationship to the suprascapular nerve, and as it passes around the spine of the scapula to the infraspinous fossa, where it may be subject to surgical injury. The anterior humeral circumflex artery arises from the axillary artery at the lower border of the subscapularis and, having passed behind the origin of the coracobrachialis and the short head of the biceps, is found beneath the deltoid on the surgical neck of the humerus. Here it divides into ascending and descending branches. The posterior humeral circumflex artery, a far more substantial vessel, arises likewise from the axillary artery at about the same level as the anterior. It passes posteriorly through the quadrilateral space, accom-

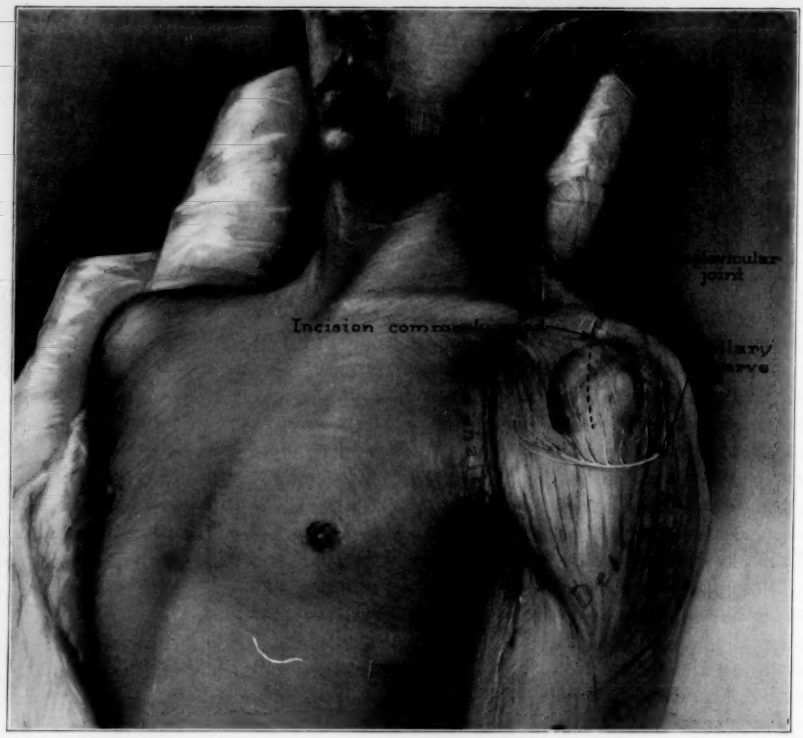

FIG. 3

The sitting position, with the shoulder projecting well beyond the border of the operating table. This position greatly facilitates the surgical exposure of the anterosuperior and superolateral aspects of the scapulohumeral joint, the subacromial bursa, and the musculotendinous cuff. Note position of the axillary nerve in relation to incisions which separate the fibers of the deltoid.
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panying the axillary nerve to wind around the surgical neck of the humerus and distribute branches to the deep surface of the overlying deltoid muscle.

The thoraco-acromial artery, a short trunk, arises from the second part of the axillary artery and winds around the upper border of the pectoralis minor to pierce the costocoracoid membrane, where it divides into numerous branches. A clavicular branch passes upward towards the clavicle. Several large pectoral branches proceed downward between the two pectoral muscles, where they anastomose with the lateral thoracic and lateral branches of the intercostal vessels. The acromial branch runs laterally beneath the tendon of the pectoralis minor or above it, frequently supplying twigs to the deltoid. This branch is often found on the inferior aspect of the coracoid process, where it may prove troublesome in dissections in the neighborhood of that structure. A final branch, the deltoid ramus, takes origin from the common trunk and runs distally in the intermuscular interval between the pectoralis major and the deltoid.

SURGICAL APPROACHES TO THE SCAPULOHUMERAL JOINT

The surgical exposure of the scapulohumeral joint is difficult, because of the special anatomical relation of the structures which surround it. On the anterior, lateral, and posterior surfaces, the joint is shrouded by the deltoid. To avoid permanent damage to this muscle, incisions which pass through it must be made parallel to the direction of its fibers.

They should be limited in their extent to an area between the margins of the acromion and the axillary nerve, where it passes from back to front around the upper portion of the shaft of the humerus (Fig. 2). On its superior surface the joint is covered by the protective bony and ligamentous arch formed by the coracoid, the acromion process, and the coraco-acromial ligament. This arch is anchored in position anteriorly by the outer end of the clavicle, articulating with the acromion process to form the acromioclavicular joint. The medial and lateral margins of the outer portion of the clavicle, the acromion, and the spine of the scapula provide attachments for the trapezius and deltoid, respectively. Full access to this part of the joint may require osteotomy of the acromion process, or subperiosteal detachment of the origin of the deltoid from the outer third of the clavicle and the adjoining borders of the acromion.

Exposure of the anterior aspect of the joint is generally obtained by separation of the adjacent margins of the pectoralis major and the deltoid, but in many instances this approach is unsatisfactory unless it is enlarged by separating the origin of the deltoid from the clavicle. In a similar manner, the posterior aspect of the scapulohumeral joint can be disclosed in its entirety by osteotomy of the acromion, or by detachment subperiosteally of the deltoid from the spine of the scapula and the lateral margin of the acromion process.

It can now be seen clearly that complete exposure of the anterior, superior, lateral, and posterior aspects of the scapulohumeral joint can be secured by a curvilinear skin incision which follows the anterior margin of the deltoid and its line of origin from the clavicle, acromion, and spine of the scapula. This permits the origin of the deltoid to be reflected subperiosteally from the clavicle, the inferior margin of the spine of the scapula, and the superior surface of the acromion process. The remainder of the deltoid attachment to the acromion is freed by osteotomy of its lateral border. This method of detaching the deltoid, with an edging of periosteum and bone, provides for adequate repair with sound healing. A segment of this curvilinear incision may be utilized for exposure of one or more aspects of the scapulohumeral joint. Therefore, this incision might appropriately be termed the "comprehensive" incision for exposure of the scapulohumeral joint (Fig. 5).

The Sitting Position for Operations upon the Shoulder

In operations upon the shoulder, the selection of the proper position of the patient and its maintenance throughout the entire operation is of great importance. The surgeon must work with the part supported and held in such a way as to provide easy access to the structures which he wishes to expose. He should not be handicapped by a faulty position of the patient on the operating table. The authors have found that the supine position in operations upon the shoulder does not provide adequate access to its superior, posterior, and lateral aspects. Also, under these conditions, the surgeon works in an awkward and uncomfortable posture which produces both mental and physical fatigue. These difficulties can be obviated by the use of the sitting position (Fig. 3). The authors first used this method of procedure in 1925, in the St. Louis unit of the Shriners' Hospital for Crippled Children. It was found invaluable in arthrodesis of the shoulder for patients disabled by residual paralysis due to anterior poliomyelitis. Only in this way could we accurately palpate the bony landmarks which enabled us to secure the optimum position for function.

From that time on, we extended the use of the sitting position to include practically all operations on the scapulohumeral joint. It is particularly successful in removal of calcified deposits in the musculotendinous cuff, in rupture of the supraspinatus, recurrent dislocation of the shoulder, and fractures of the head and neck of the humerus and its tuberosities. It has also proved of great advantage in operations on the brachial plexus and for the removal of a cervical rib.

Experience has shown that the preferred position is with the trunk at approximately 70 degrees with the horizontal plane, the shoulder extended well beyond the margin of the table, the head turned to the opposite side, and the sterile drapes arranged to leave the

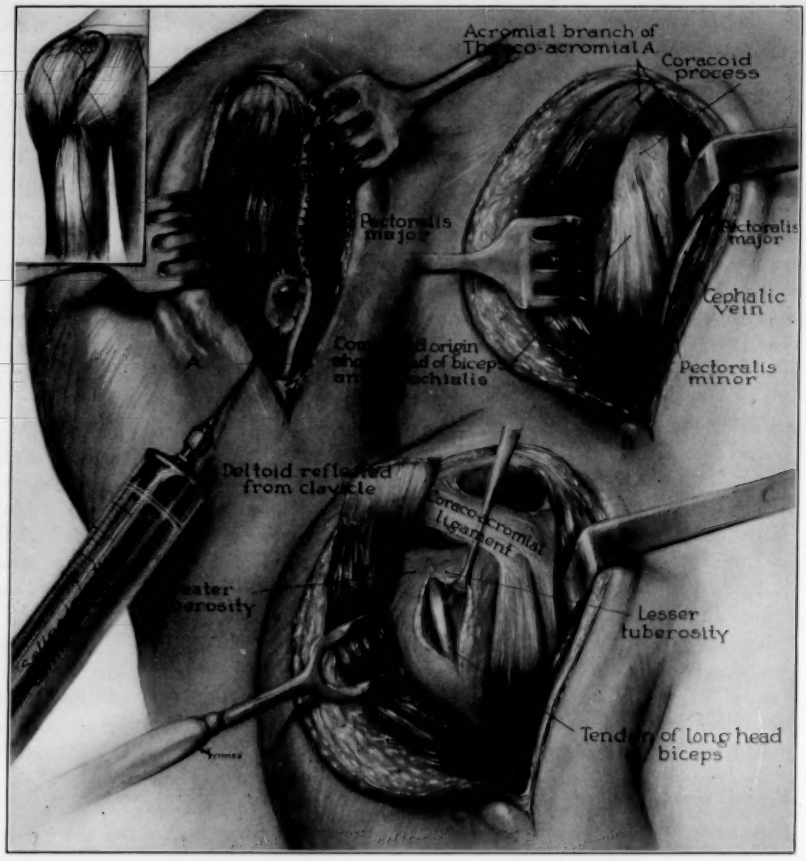

FIG. 4

Approach to the anterior aspect of the shoulder with curved incision to prevent excessive scar (method of Hitchcock).
A: Saline injection to define cephalic vein (method of Bechtol).
B and *C:* Exposure of deep structures.

arm entirely free, in order to permit motion of the scapulohumeral joint. A tilting operating table which holds the hips and knees in moderate flexion gives the desired slope upward behind the knees, so that the thighs rest against an inclined plane. In this way the patient does not slide downward and out of position. The tilting operating table also permits a quick change in the position of the patient in case of emergency, such as difficulty with the anaesthetic. Recently the authors have used a folding dental chair, which is preferable because it permits two assistants to work with the surgeon, one on each side.

Local anaesthesia is particularly suitable for operations upon the shoulder, and the authors have used it extensively in the removal of deposits from the musculotendinous cuff and for repair of rupture of the supraspinatus tendon. Active movement of the arm by the patient during the operation helps materially in exposure of this joint through limited incisions, and also aids in diagnosis and in the repair of damaged structures.

In addition, the sitting position is readily adaptable to operations upon the shoulder requiring general anaesthesia. Here it is of importance to support the trunk on the chair or the folding table by means of straps placed around the legs, thigh, pelvis, and chest.

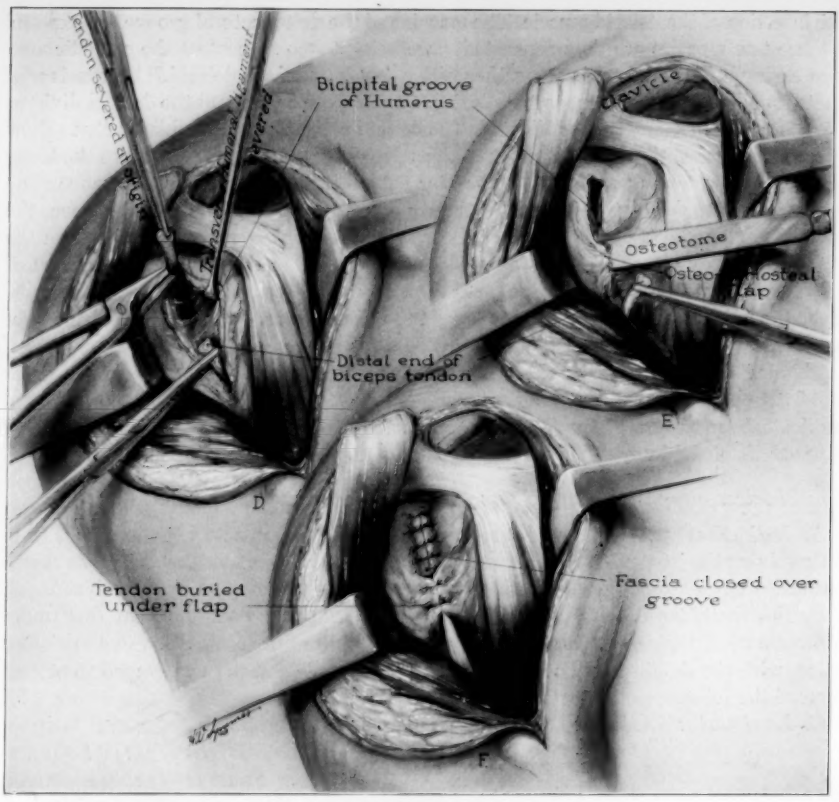

FIG. 4 (*continued*)

D: Excision of proximal portion of tendon of the long head of the biceps.
E and *F:* Fixation of distal portion of this tendon in the bicipital groove with osteoperiosteal flap, as described by Hitchcock and Bechtol. Method of treatment in certain cases of tenosynovitis of the tendon of the biceps and associated subacromial bursitis.

The head should be held on a special head rest in a posture which prevents strain on the neck. In the authors' experience, intratracheal anaesthesia is preferable and eliminates completely the need for the anaesthetist to turn and twist the head in order to give the usual inhalation anaesthesia. Failure to observe these principles of support for the trunk and head and to avoid torsion on the neck may produce serious injury with rotatory dislocation of the cervical spine. Wilson observed a case of cervical dislocation that resulted from faulty use of the sitting position.

APPROACHES TO THE ANTERIOR ASPECT OF THE SCAPULOHUMERAL JOINT

1. *Deltopectoral Incision*

A. *Indications:* This incision is indicated for (1) fractures and dislocations of the shoulder; and (2) tenosynovitis and dislocation of the long head of the biceps.

B. *Position of the Patient:* The patient is supine with the arm at the side, or supported in varying degrees of abduction by an arm board.

C. *Landmarks:* The following landmarks should be observed: (1) outer one-third of the clavicle; (2) acromion; (3) coracoid process; and (4) deltopectoral groove.

D. *Incision:* An oblique incision is made in the skin along the anterior border of the deltoid, from the junction of the middle and outer thirds of the clavicle, downward almost

to the insertion of the deltoid muscle. The margins of the deltopectoral groove are exposed and these two muscles are then separated, care being taken to protect the cephalic vein by preserving its fascial covering, together with a few fibers of the deltoid. The vein is now retracted medially, and numerous tributaries of the cephalic vein and the deltoid division of the thoraco-acromial artery are ligated. The deltoid muscle is retracted laterally to show the coracoid process, the deltoid portion of the subacromial bursa which overlies the lesser tuberosity, the anterior portion of the greater tuberosity, and the bicipital groove. The bursa is opened to reveal the greater tuberosity of the humerus, the bicipital groove, the tendon of the long head of the biceps, and the anastomosing vessels which arise from the anterior circumflex artery and pass upward and downward in the groove. By rotation of the humerus and separation of the long and short heads of the biceps, the lesser tuberosity and the medial lip of the bicipital groove, with the insertions of the tendons of the subscapularis, the teres major, and the latissimus dorsi, are exposed.

This incision may be enlarged above by detachment of the deltoid from the outer third of the clavicle and the anterior margin of the acromion process, or below by partial subperiosteal separation of the tendinous insertions of the pectoralis major and deltoid into the shaft of the humerus (Figs. 3 and 4).

2. *The Shoulder-Strap Incision of Henry*

A. *Indications* are as follows: (1) tumors of the anterior aspect of the joint; (2) fractures involving the joint; (3) arthrodesis of the joint; (4) recurrent dislocation of the shoulder; and (5) tenosynovitis or dislocation of the tendon of the long head of the biceps.

B. *Position of the Patient:* The patient is either supine, with a small flat sandbag under the lower part of the scapula on the side of the operation; or, preferably, in the sitting position, with the shoulder well over the margin of the table and the arm draped to permit motion of the joint.

C. *Landmarks:* The landmarks are the same as those for the deltopectoral incision.

D. *Incision:* The anterior part of the skin incision is the same as for the deltopectoral incision. At the upper end, this incision is extended from the tip of the coracoid over the superior aspect of the shoulder to the level of the spine of the scapula. The cephalic vein is retracted medially with a few fibers of the deltoid muscle; and the deltopectoral groove is followed to the clavicle, thus exposing the anterior surface of the outer third of this bone and the adjacent margins of the acromion process. With a thin-bladed osteotome the origin of the deltoid is detached, with a thin shaving of bone from the anterior margins of the clavicle and the anterior part of the lateral margin of the acromion. Care should be taken not to cut too

FIG. 5

Exposure obtained by anterior and lateral segment of the "comprehensive" incision.

deeply into the bone. This approach exposes very adequately the coracoid process and its attached structures, the large subacromial bursa, the bicipital groove, and the tendons inserting into the greater tuberosity. Upon incision into the bursa, these bony structures and their tendinous insertions are readily viewed. Elevation of the origin of the deltoid may be continued around the lateral and posterior margins of the acromion and the adjacent spine of the scapula, to give complete exposure of the superior aspect of the shoulder joint.

Recently the authors have exposed the deeper aspects of the scapulohumeral joint, including the anterior margin of the glenoid, through the anterior segment of the curvilinear or comprehensive incision, with detachment of the deltoid from the anterior margins of the clavicle and acromion (Fig. 5). The coraco-acromial ligament is divided, one-half inch medial to its attachment to the acromion. The periosteum over the coracoid is then incised proximal to the coracoid insertion of this ligament, and an osteotomy of this bone is performed. With the coraco-acromial ligament being used as a handle, the distal segment of the coracoid is turned downward and inward with the origin of the coracobrachialis and short head of the biceps. The upper and lower borders of the subscapularis are thus exposed and it is transected at the junction of its muscle and tendon, about one inch medial to its insertion into the lesser tuberosity of the humerus. An incision is made through the anterior capsule, so that the anterior rim of the glenoid can be inspected.

In recurrent dislocation, the tearing of the capsule from the labrum or the detachment of the labrum from the bone itself can be identified and repaired. This repair is facilitated by a specially designed retractor, with which the head of the humerus can be displaced laterally and posteriorly, and by the use of instruments which permit drilling of the anterior margin of the glenoid. At present the writers use the Putti-Platt method of repair, in which the anterior surface of the neck of the scapula is denuded and the distal segment of the subscapularis is sutured to the medial tip of the anterior capsule. Further reinforcement is then secured anteriorly by suture of the muscle belly of the subscapularis to the scarified tendinous cuff which overlies the greater tuberosity or the bicipital groove. This method was described in a recent article by Osmond-Clarke.

Closure of the wound is accomplished by suturing or nailing the tip of the coracoid to the base of the coracoid process, or by subperiosteal excision of the tip and suture of the origin of the coracobrachialis and the short head of the biceps to the base of the coracoid. The deltoid is turned back to its normal position and sutured to the clavicle and acromion. Henry advocated resuture by a single loop suture around the clavicle. For postoperative care, he suggested immobilization by sling or Velpeau bandage to maintain the arm at the side. The period of immobilization depends upon the nature of the injury.

3. *Longitudinal Separation of the Fibers of the Deltoid*

A. *Indications:* This method is recommended for (1) calcified deposits in the musculotendinous cuff; (2) rupture of the supraspinatus; and (3) fracture of the tuberosities of the humerus.

Note: The site of incision for removal of a calcified deposit depends upon its precise location within the musculotendinous cuff. To determine the exact position of this deposit, the authors use roentgenograms and palpation for point tenderness. Roentgenograms are taken of the scapulohumeral joint in the positions of external and internal rotation. A vertical view to show the bicipital groove is also taken. In external rotation a calcified deposit in the tendon of the supraspinatus is clearly shown above the greater tuberosity of the humerus, while in internal rotation the outline of the deposit is obscured by the overlapping shadow of the greater tuberosity. Exactly the reverse is true when the deposit lies posteriorly, within the tendon of the teres minor. Here, in the position of external rotation, the shadow of the greater tuberosity is superimposed on the shadow of the deposit; in internal rotation the deposit is clear and well defined laterally, and just inferior to the

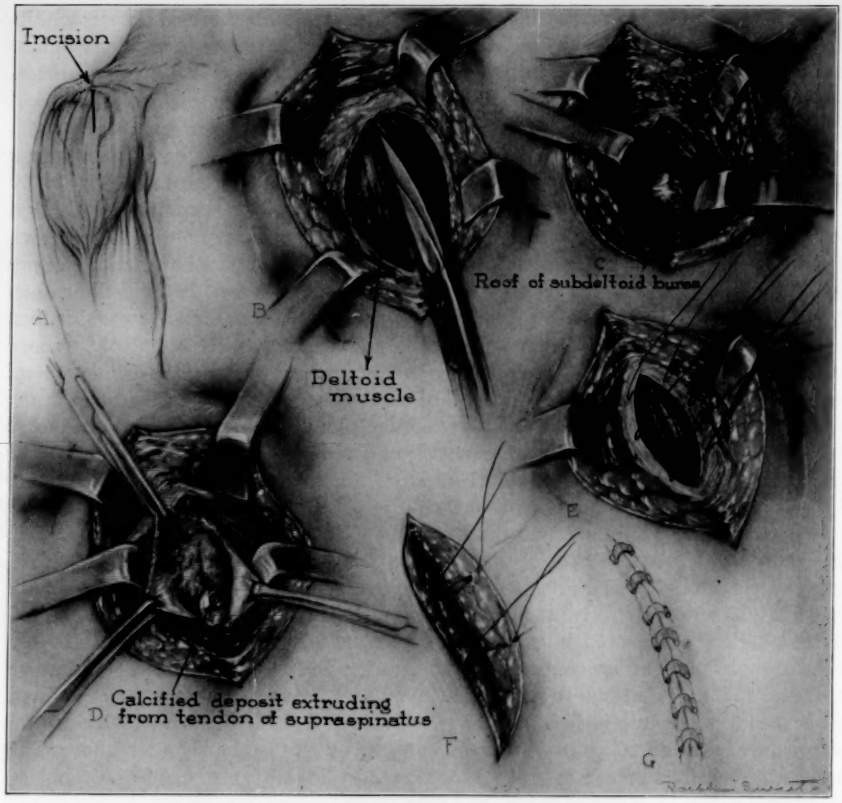

FIG. 6

The muscle-splitting approach to the subacromial bursa and musculotendinous cuff.
(Reproduced, by permission of Appleton-Century-Crofts, Inc., from chapter by LeRoy C. Abbott, M.D., to appear in *Operative Technic*, edited by Warren H. Cole, M.D.)

greater tuberosity. Vertical views show the relation of these deposits to the margins of the bicipital groove and are, therefore, helpful in determining whether they lie in the subscapularis, supraspinatus, or infraspinatus tendons.

While roentgenograms are an important aid in localization, in patients with acute symptoms, experience has taught us to rely upon point tenderness as the chief guide to the site of the incision.

It is true that most deposits can be removed through an anterior incision and by rotation of the arm to bring all aspects of the insertion of the cuff beneath the incision. However, if the deposit is in the tendon of the teres minor, in an acute case with marked spasm of the muscles or in a chronic case with adhesions, internal rotation of the arm may be so restricted that it prevents access to the deposit. In such instances, where there is local tenderness on the lateral or posterolateral aspect of the shoulder, it is best to make an incision on the anterolateral or lateral surface. In an occasional case where motion is limited by extreme spasm, the authors have found it necessary to relieve this condition by supplementing local anaesthesia with intravenous sodium pentothal.

B. *Position of the Patient:* The patient is in a sitting position with the arm free at the side and the shoulder over the margin of the back rest. The elbow is held at a right angle, with the forearm supinated.

C. *Landmarks:* The landmarks are (1) acromioclavicular joint; (2) acromion; (3) humerus; and (4) bicipital groove.

D. *Anaesthesia:* Local anaesthesia, consisting of 1 per cent. novocain with adrenalin, is preferable except in cases where muscle spasm is marked and the patient is unable to relax. In such cases the authors usually employ sodium pentothal intravenously.

E. A vertical incision of the skin is made along the upper segment of a line which is projected from the acromioclavicular joint to the middle of the anterior aspect of the elbow, with the arm at the side and the elbow flexed to a right angle (Fig. 6). To avoid injury to the axillary nerve, the incision should extend downward for no more than one and one-half inches from the anterior margin of the acromioclavicular joint. The fascia covering the deltoid is split, and its fibers, which interlace in a bipenniform fashion, are separated and retracted with a self-retaining retractor. In performing this step, the authors have found electrocautery useful for the coagulation of the small vessels as they cross the field of separation of the muscle fibers. A dry field is thus maintained with minimum damage to tissues. The roof of the subdeltoid bursa is seen, but not entirely divided until the deltoid fibers are separated throughout the length of the wound, particularly at the top of the incision over the margin of the acromion. With the opening of the bursa and with voluntary movement of the arm, the insertion of the musculotendinous cuff into the tuberosities, the bicipital groove, and the anastomosing branches of the suprascapular and circumflex vessels are exposed. The musculotendinous cuff can be seen as far back as the insertion of the teres minor, although this is sometimes difficult. Therefore, as described in previous paragraphs, for complete rupture of the supraspinatus and for evacuation of calcified deposits in the posterior aspect of the cuff, a similar incision is used, but is placed farther laterally.

Approaches to the Superolateral Aspect of the Shoulder Joint

1. *Longitudinal Splitting of the Deltoid Fibers*

2. *Longitudinal Splitting of the Deltoid Fibers with Partial Separation of the Deltoid from the Margin of the Acromion*

A. *Indications:* The indications are as follows: (1) removal of calcified deposits which lie posteriorly; and (2) the repair of complete rupture of the supraspinatus.

B and C. The *position of the patient* and the *landmarks and incisions* are the same as for the anterior muscle-splitting incision, except that the incisions are placed over the superolateral aspect of the shoulder. They begin on the superior surface of the acromion process and extend downward over its lateral border and the upper part of the deltoid. The separation of the fibers of the muscle must not extend farther downward than from an inch to an inch and a half below the lateral border of the acromion, because of the danger of injury to the axillary nerve. By subperiosteal removal of the deltoid origin from the acromion at the margins of the incision, the authors have repaired both partial and complete ruptures of the supraspinatus. In the former, however, removal of irregular projection of scar tissue, bone, and the stub of tendon attached to the greater tuberosity will permit the smooth passage of this latter structure beneath the acromion and will relieve the symptoms.

3. *Transverse Division of the Deltoid*

A. *Indications:* Arthrodesis of the shoulder joint.

B. *Position of the Patient:* The patient may be in either the supine or the sitting position.

C. *Approach:* The incision has two components. The horizontal portion passes around the shoulder from front to back, one-half inch below the lateral margin of the acromion. The vertical arm, beginning in the horizontal incision over the greater tuberosity of the humerus, extends downward two inches. Two flaps of skin and subcutaneous tissue are

thus formed. A deep incision is then made through the deltoid, at the tip of the lateral margin of the acromion. The capsule is opened and freely excised to gain exposure of the joint. The long head of the biceps, identified anteriorly, is separated from the groove. The acromion process is denuded of all soft tissues on its inferior and superior surfaces, and fusion may then be accomplished by removal of the joint cartilage and mortising the acromion into the tuberosity of the humerus.

4. *Separation of the Deltoid from Its Origin on the Clavicle and Acromion*

This approach, described by Cubbins, Callahan, and Scuderi and by Henry, is similar to Henry's shoulder-strap incision, already described. A superolateral incision is begun anteriorly and curved around the margin of the acromion to the root of the spine of the scapula, and the deltoid is separated from its origin on the clavicle and acromion. This approach gives an excellent view of the anterosuperior and superolateral aspects of the joint, and may be used for fractures, arthrodesis of the shoulder joint, and repair of the musculotendinous cuff.

5. *Osteotomy of the Acromion Process*

A. *Saber-Cut Incision of Codman*

1. *Indications:* The indications are (1) repair of the musculotendinous cuff; (2) recurrent dislocation of the shoulder; (3) fixation of the tendon of the long head of the biceps in the bicipital groove; and (4) repair of fractures in the region of the greater and lesser tuberosities.

2. *Position of the Patient:* The patient is supine with the entire shoulder exposed laterally and posteriorly and the arm free; or, as in the authors' work, the patient is placed in the sitting position.

3. *Approach:* The incision begins anteriorly, one inch below the level of the acromion process, and passes directly upward over the acromioclavicular joint and then down the back of the shoulder to one inch below the spine of the scapula. The fibers of the deltoid are separated anteriorly and posteriorly from above downward, and the ligaments of the acromioclavicular joint are severed. The acromion process is divided by an osteotome, the division extending backward from the joint to a point medial to the angle of the acromion. The divided acromion and attached deltoid are turned downward and retracted laterally to expose the subacromial bursa, the capsule of the shoulder joint, and the insertion of the muscles which form the musculotendinous cuff. This retraction should be done with care, to avoid possible injury to the suprascapular nerve and transverse scapular artery, which pass through the suprascapular notch.

The tendon of the long head of the biceps is exposed and, if the capsule is opened, the head of the humerus and the anteroposterior margin of the glenoid are brought into view.

The objection to this approach, as described by Codman, is that there is a delay of postoperative movement. The authors also have had two cases in which there was non-union of the acromion process, and second operations were necessary. As in all deltoid-splitting incisions, care must be used to avoid injury to the axillary nerve.

B. *Transacromial Approach of Darrach and McLaughlin:* The following approach, as described by Darrach and McLaughlin, is preferable to the Codman approach because the acromioclavicular joint is preserved. The incision parallels the strap or suspender line in the normal skin creases of the region lateral to the acromioclavicular joint. It extends from the posterior aspect of this joint to a point two inches in front of the anterior border of the acromion. Anteriorly the bursa and the coraco-acromial ligament are exposed by separation of the fibers of the deltoid. McLaughlin emphasized the importance of splitting

the fibers of the deltoid from above downward, beginning at the margin of the acromion, for in this way no unnecessary splitting is done and there is less danger of injury to the circumflex vessels and the axillary nerve.

Exposure of the shoulder joint is then obtained by osteotomy of the acromion, in a line mid-way between the acromioclavicular joint and the lateral border of the acromion. The deltoid is retracted laterally with the outer fragment of the bone. For repair of the musculotendinous cuff, a more oblique osteotomy, deviating laterally to emerge at the lateral lip of the acromion, gives adequate exposure and a better cosmetic result. The interior of the shoulder joint may be inspected by incisions through the musculotendinous cuff, between the margin of the glenoid and the anatomical neck of the humerus.

McLaughlin prefers this approach to others for many reasons. In fractures, bone fragments can be removed without being dragged through the brachial plexus. Repair of the labrum glenoidale and the anterior capsule in recurrent dislocation is carried out from within the joint, avoiding the trauma of sectioning the coracoid and its attachments as well as of dividing the subscapularis tendon. The removal of the fragment of the acromion also makes a less prominent fulcrum for impingement of the greater tuberosity in recurring dislocations of the shoulder. The Nicola transplant of the biceps tendon, reduction and fixation of fractures, and other reconstructive procedures on the musculotendinous cuff can readily be performed through this exposure.

Approaches to the Posterior Aspect of the Joint

1. *Approach of Kocher*

A. *Indications:* This approach is indicated for (1) posterior dislocation of the head of the humerus; (2) certain fractures of the head of the humerus and the posterior portion of the glenoid; (3) excision of the shoulder joint; and (4) tumors of the neck of the scapula.

B. *Position of the Patient:* As recommended by Kocher, the patient is placed prone with his arm abducted on an arm board and pillows under the chest on the side of the operation; the head is turned to the opposite side. An alternate position, which the authors prefer, is the sitting position with the shoulder well over the side of the table and the arm free.

C. *Landmarks:* The landmarks are (1) acromioclavicular joint; (2) acromion process; (3) spine of the scapula; and (4) posterior border of the deltoid.

D. *Incision:* The incision begins at the acromioclavicular joint and extends backward along the outer border of the acromion to the spine of the scapula. It is then curved downward, ending two fingerbreadths above the posterior fold of the axilla. The superior and posterior ligaments

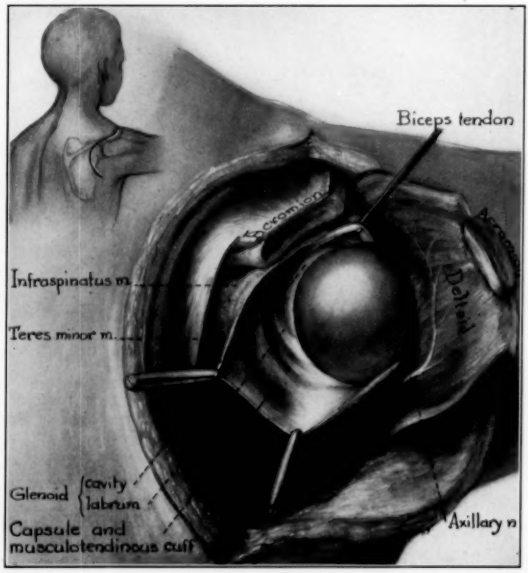

FIG. 7

The posterior approach with subperiosteal detachment of the deltoid and osteotomy of the lateral margin of the acromion. This is used especially for arthrodesis of the shoulder, with the patient in the sitting position.

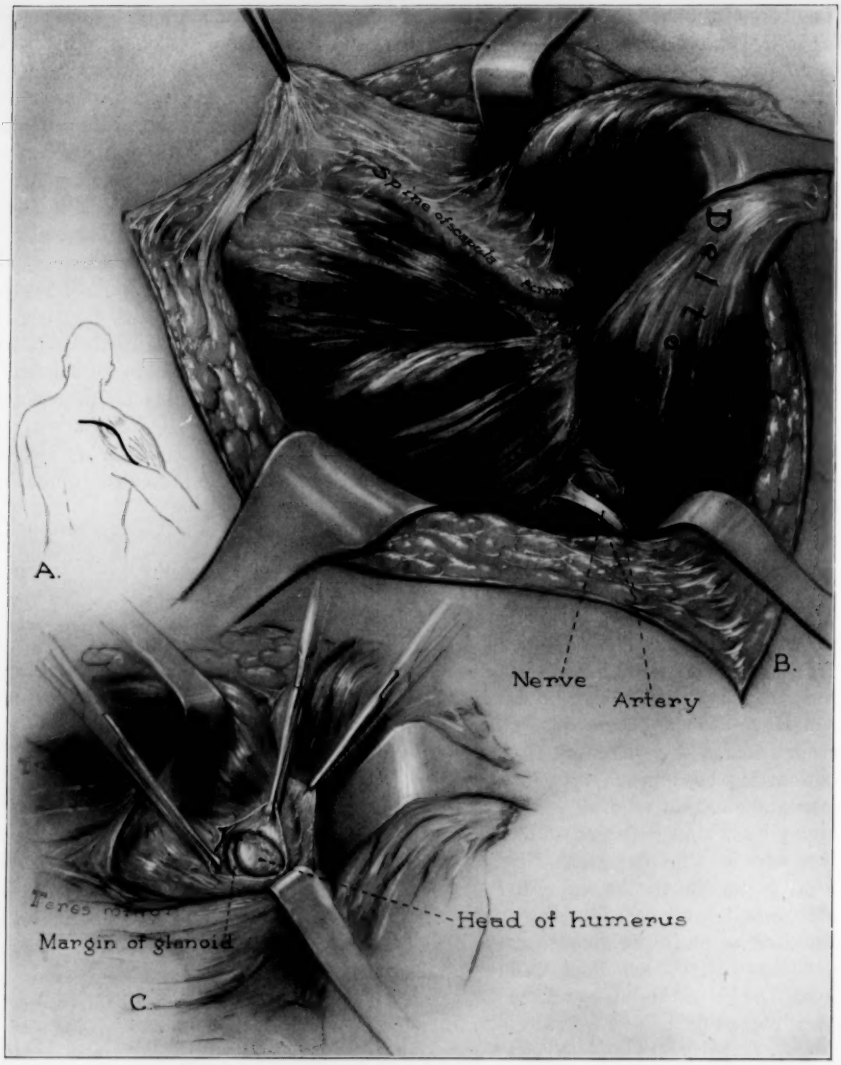

FIG. 8

A and *B:* Posterior approach for exposure of the posterior inferior portions of the scapulohumeral joint, between the infraspinatus and teres minor (method of Bennett).
C: Capsule incised in line of fibers, exposing head of humerus and margin of glenoid.

of the acromioclavicular joint are divided, and the trapezius is separated from the spine of the scapula. Through the descending limb of the incision, the dense fascia over the posterior border of the deltoid is divided.

The deltoid origin is then freed from the scapular spine as far laterally as the posterior margin of the acromion, a margin of tissue being left on the bone for resuturing. By detaching the upper border of the infraspinatus, an interval is developed so that the finger can be passed around the root of the acromion. Here the suprascapular nerve and the transverse scapular artery must be carefully isolated and protected. The acromion is then oste-

otomized obliquely and the outer segment is retracted with the deltoid. As an alternative to division of the bone, the deltoid is separated from the spine of the scapula and the acromion, as far forward as the acromioclavicular joint. Lifting this deltoid curtain readily reveals the head of the humerus and the muscles inserting into the greater tuberosity. The capsule is then divided over the very top of the humeral head. The tendon of the long head of the biceps is freed from its groove and retracted forward.

The external rotators are divided, enough tendon being left attached to the bone for suturing, and the muscles are drawn backward. The anterior portion of the capsule should be left intact, even though in some cases it may be necessary to detach the insertion of the subscapularis. The integrity of the anterior portion of the capsule limits the tendency of the head of the humerus to become displaced upward and inward toward the coracoid process. By this method a wide exposure of the head of the humerus is obtained without impairment of function of the deltoid.

The writers have used a modification of the Kocher approach for arthrodesis of the scapulohumeral joint, with the patient in the sitting position (Fig. 7). For this operation the dental chair is particularly suitable, as the entire posterior and superior aspects of the shoulder with its bony landmarks are accessible to the surgeon. Beginning at the anterior border of the acromion, the incision is curved over its lateral margin and then along the inferior edge of the spine of the scapula to the junction of its inner and middle thirds. From here it turns outward and downward in a gentle curve, to follow the posterior margin of the deltoid for a short distance, and it terminates near the inferior angle of the scapula. In the lower part of the wound the margin of the deltoid is identified and followed to its origin from the spine of the scapula. The periosteum is divided over the center of the spine of the scapula and acromion process, and reflected laterally with the origin of the deltoid as far as the edge of the acromion. This edge is divided with an osteotome, thus completely freeing the origin of the posterior segment of the deltoid with the exception of the innermost part of its origin, which is often transected. This muscle is then turned outward to expose the greater tuberosity of the humerus and the musculotendinous cuff. The teres minor tendon should be identified here, as it forms the upper boundary of the quadrilateral space which contains the axillary nerve and the posterior circumflex vessels.

The tendinous insertion of the cuff is divided, a stub being left attached to the greater tuberosity to facilitate repair. The cuff is turned medially to expose the capsule of the joint. With division of this structure, the posterior aspect of the joint is readily viewed. The cartilage is removed from the glenoid and the head of the humerus with special gouges. The inferior and superior surfaces of the acromion are scarified, and its junction with the root of the spine of the scapula is partially divided with an osteotome. A vertical groove is cut in the humerus, directly medial to the greater tuberosity. With the arm abducted to approximate the denuded glenoid and head of the humerus, the osteotomy of the acromion is completed by bending it and fitting it into the groove in the humerus. Fixation of the joint is secured by screws, which are turned through the outer cortex of the upper portion of the shaft and the head of the humerus, and into the glenoid. The insertion of the musculotendinous cuff is pulled up and over the acromion and stitched to the periosteal insertion of the trapezius. The inferior margin is then stitched to the stub of the cuff on the greater tuberosity. This binds the acromion into the groove of the humerus and gives additional fixation. The origin of the deltoid is repaired with interrupted sutures, and the skin is closed in the usual manner.

2. *Posterior Approach of Harmon*

A. *Incision:* The incision is begun in the middle of the spine of the scapula and is carried outward to the angle of the acromion. The origin of the deltoid on the spine of the scapula and the acromion is detached and reflected laterally and inferiorly. In this step the deltoid should not be retracted below the level of the belly of the teres minor, lest the axil-

lary nerve be injured. With the arm in a neutral position as regards rotation, a vertical incision is made through the tendinous portion of the rotator cuff, just above the belly of the teres minor and the quadrilateral space. Harmon stated that this gives extensive exposure to the humerus, being inferior only to the saber-cut method in the extent of the exposure.

3. *Approach of Rowe and Yee*

A. *Incision:* The incision is begun at the junction of the middle and inner thirds of the spine of the scapula and is extended laterally to the outer segment of the spine. It is then curved downward over the posterior aspect of the shoulder joint for about four inches. Retraction of the skin exposes the deltoid origin from the spine of the scapula. Approximately one and one-half inches from the medial border of the deltoid, this muscle is split in a downward direction for a distance of three inches. The portion of the muscle lateral to the vertical incision through its substance is formed into a triangular flap by subperiosteal reflection of its origin from the spine of the scapula. This exposes the infraspinatus and teres minor. The approach to the joint is secured by separating these two muscles and freeing the infraspinatus from the underlying capsule. The tendon of attachment of the infraspinatus is divided half an inch from its insertion into the greater tuberosity, and is retracted medially. Retraction of the teres minor inferiorly exposes the capsule of the posterior and inferior aspects of the shoulder joint. Rowe and Yee emphasized the importance of keeping the incision above the teres minor, in order to avoid injury to the axillary nerve which passes here through the quadrilateral space. The interior of the posterior and inferior aspects of the shoulder joint can be exposed adequately by a vertical incision through the capsule.

4. *Approach of Bennett*

In 1941, Bennett described an approach to the posterior aspect of the shoulder for removal of deposits of bone on the posterior-inferior border of the glenoid fossa. He showed that these deposits occur in baseball pitchers, as a result of excessive use of the arm and a tremendous pull on the posterior portion of the capsule and the tendon of the long head of the triceps.

A curved incision is made over the posterior aspect of the shoulder, and the origin of the deltoid is detached from the spine of the scapula and retracted laterally. The posterior capsule of the joint is exposed in the interval between the tendons of the infraspinatus and teres minor. The infraspinatus is supplied by the suprascapular nerve, entering its substance from above, while the teres minor is supplied by the axillary nerve which enters it from below. Therefore, there is little danger of injury to either nerve by separation of the adjacent borders of these two muscles. The authors have found this approach satisfactory for exposure of the postero-inferior aspect of the scapulohumeral joint (Fig. 8).

Approaches to the Inferior Aspect of the Joint

Approaches to the inferior aspect of the shoulder joint may be achieved by the method of Thomas, which reaches the capsule at the inferior aspect of the joint by an incision along the margin of the posterior fold of the axilla. To our knowledge, this approach is not in use at the present time. Other approaches to the axilla, usually for purposes of drainage of the axillary space, are made along the inferior margin of the pectoralis major. Incisions of this type may occasionally be needed for drainage of pus which has migrated from the shoulder joint to the axilla; or, more commonly, for accumulations of pus arising from infected axillary glands.

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SURGICAL TREATMENT OF NON-UNION OF LONG BONES *

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This paper is based on three years' experience in the National Center of Reconstructive Surgery. We are presenting 126 cases of non-union of long bones, treated by different methods, together with their end results. Most of these cases were war wounds, many with large bone defects and severe infection.

Among the first 102 cases (Table I), sixty-four were war wounds, of which forty-two showed large bone defects. All of the forty-two and many of the others were or had been severely infected. A certain number of these men had been wounded during the "underground" fighting, when no penicillin was available and the facilities for surgical treatment of compound fractures were extremely bad.

TABLE I

NON-UNION OF THE LONG BONES

Location	Open Fractures		Closed Fractures (Early Treatment)		Total
	Without Loss of Bone Substance	With Loss of Bone Substance	Open Reduction	Non-Operative	
Femur	3	6	5	4	18
Tibia	9	10	6	4	29
Humerus	6	15	4	3	28
Both bones of forearm	3	4	5	4	16
Radius or ulna alone	1	7	2	1	11
Totals	22	42	22	16	102

TABLE II

RESULTS IN 126 CASES

Location	No. of Cases	Consolidations (Union)					Failures
		No. of Interventions			Total		
		1	2	3	Number	Per cent.	
Humerus	32	25	3	1	29	90	3
Both bones of forearm	18	17		1	18	100	0
One bone of forearm	16	15		1	16	100	0
Femur	19	14	3	1	18	95	1
Tibia	41	32	4	2	38	93	3
Totals	126	103	10	6	119	94	7

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1948.

** Created by the Ministry of War in 1944. Organized and directed by the author.

TABLE III

NON-UNION OF THE HUMERUS

Operative Method	No. of Operations	Consolidations		Failures	Average Period before Union Was Obtained (*Months*)
		No.	Per cent.		
Metallic fixation					
Encircling wire	2	2	100	0	4
Screws	4	4	100	0	2½
Küntscher nail	4	2	50	2 (1 reoperation)	3
Tibial graft					
Intramedullary	2	0		2 (1 reoperation)	
Fixed by encircling wire	4	2	50	2 (1 reoperation)	3
Fixed by screws	12	11	92	1 (1 reoperation)	3½
Küntscher nail plus graft	8	8	100	0	6
Totals					
Operations	36	29	80	7	
Cases	32	29	90	3	

Thirty-eight of these were simple fractures; sixteen of the patients had not been operated upon previously. Twenty-two had been treated by open reduction and bone-plating, often because of the impossibility of following the cases. These figures suggest that an important cause of non-union in fractures of the long bones, whether in war fractures or in the compound fractures of civil practice, is bone-plating done with improper technique.

We consider the guiding principles for the treatment of these cases to be as follows:

Before Operation

1. To eliminate the infection as completely as possible;
2. To provide, as accurately as possible, sound soft parts around the site of fracture.

At Operation

3. To maintain the best possible blood supply to the fragments;
4. To secure sound internal fixation of the fragments;
5. To obtain firm bone contact, with pressure of each fragment against the other; or, if this is impossible because a bone defect is present, firm contact of a bone graft on both fragments;
6. In all cases to bring to the site a new bone-forming tissue to secure more rapid callus formation.

After Operation

7. To obtain good circulation and nutrition of the limb by immobilization in the most favorable position and by early active exercises of the muscles, even within the plaster cast.

In our experience, when all these principles have been observed, good bony union has always occurred. All the failures have been due to the non-observance of one or more of these rules.

The aim of this paper is not to emphasize the preoperative measures, or the need for re-education. We will only note that in every case of infection, in a preliminary operation, the fibrous tissue and the infected bone were thoroughly resected and, after a saucerization, the defect was filled by sound soft tissue,—namely, a pedicled muscle flap on deep bones (such as the humerus or femur) and a pedicled skin flap on superficial bones (fore-

TABLE IV

NON-UNION OF THE FOREARM

Operative Method	No. of Operations	Consolidations		Failures	Average Period before Union Was Obtained (*Months*)
		No.	Per cent.		
Metallic fixation					
Plate	9	6	67	3	5
Nail	9	7	78	2	4
Tibial graft with screws	35	32	91	3	4½
Nail and graft	4	4	100	0	4
Totals					
Operations	57	49	86	8	
Cases					
Two bones	18	17	94	1*	
One bone	16	16	100	0	
Total cases	34	33	97	1	

* Union of one bone, non-union of the other.

TABLE V

NON-UNION OF THE FEMUR WITHOUT LENGTHENING (WITH OR WITHOUT MODERATE BONE DEFECT)

Operative Method	No. of Operations	Consolidations			Failures	Average Period before Union Was Obtained (*Months*)
		Normal	Delayed or with Complications	Per cent.		
Metallic fixation						
Encircling wire	1	1				5
Küntscher nail	10	7	2	90	1*	5
Graft						
Iliac	1 (after nailing)	1				3
Tibial	1	1				5
Sliding	1	1				3
Küntscher nail plus tibial graft	3	3		100		3
Totals						
Operations	17	14	2	94	1	
Cases	16	13	2	94	1	

* Callus, but pain on walking; x-ray result mediocre.

arm or tibia). A delay of two months for the upper extremity and of four months for the lower extremity was always observed after complete healing before the bone operation was performed.

The incidence of recurrent infection is quite different for the upper and lower ex-

FIG. 1-A

April 21, 1947. Non-union of humerus of three years' duration.

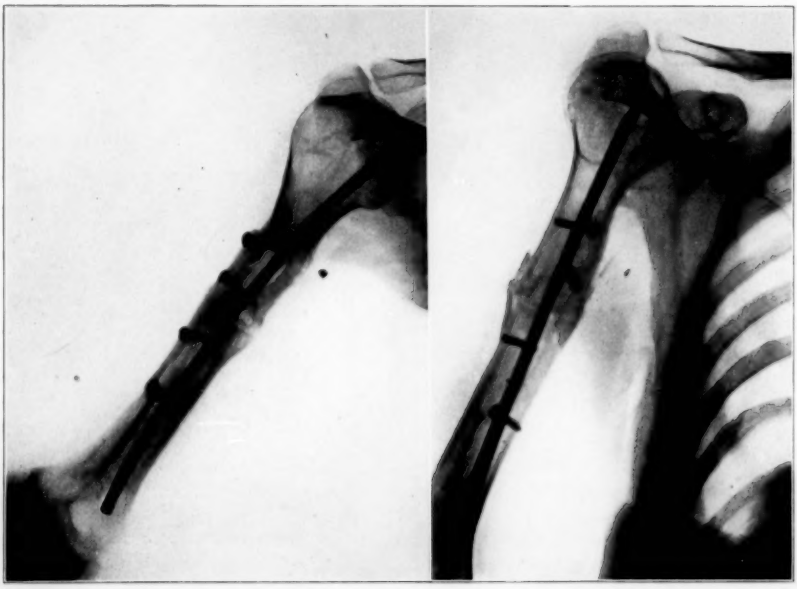

FIG. 1-B

October 6, 1947. Six months after treatment with intramedullary nail and tibial graft.

FIG. 2-A

January 6, 1947. Non-union of forearm with infection.

FIG. 2-B

June 4, 1947. Union five months after tibial graft.

tremities (Table II). In sixty-six cases of non-union of the humerus or forearm, there was only one infectious flare-up resulting in failure. In sixty cases of non-union of the femur or tibia, serious flare-ups occurred in eight cases, resulting in complete failure in three, and in long-persisting sinuses in five cases.

FIG. 3-A

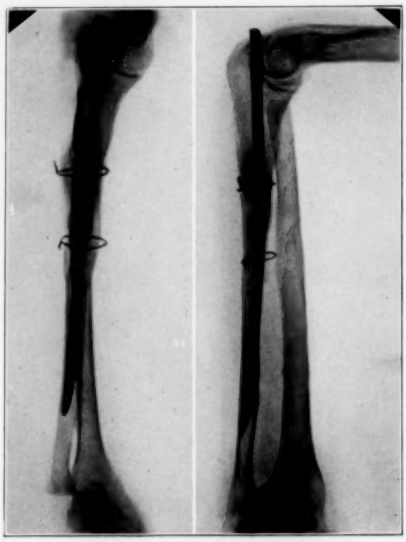

FIG. 3-B

Fig. 3-A: May 30, 1947. Monteggia fracture with non-union of ulna.
Fig. 3-B: October 11, 1947. Union four and one-half months after nailing and grafting. (An iliac graft was used.)

This difference is due, in our opinion, to the very deep infection of the muscles in war wounds of the thigh and, in non-union of the tibia, to the reopening of the suture line by infectious necrosis of the flap.

Three types of bone operations have been used in most of these cases:

1. Metallic fixation, particularly by intramedullary nailing (Küntscher method);
2. Bone graft,—a tibial graft with screws in a large number of cases, with bone chips in some cases;
3. Bone graft combined with intramedullary nailing. This method is believed to be the best in many cases.

Other methods were used, but only in a small number of cases. A comparative study of the results with the three methods just mentioned has been done for the different long bones.

UPPER EXTREMITY

Non-Union of the Humerus

In twelve of thirty-two cases, the tibial onlay graft was used, fixed by screws, with only one failure due to recurrent infection (Table III). This is an excellent method. When a bone defect is present, either the bone ends can be brought together or the defect can be bridged by the graft. This bridging procedure was so consistently successful that we think it is advisable to maintain the normal length of the limb in all cases except those in which, because of an associated nerve defect, the shortening of the bone permits an end-to-end nerve suture. This suture has always been performed in the same stage.

To prevent possible fracture of the graft, the arm has to be kept in an abduction plaster cast for at least sixteen weeks. This, of course, is a serious drawback. This long period of immobilization can be avoided by the use of the Küntscher nail. Of four cases in which the nail was used alone, two were successes and two were failures. In one case the fragments pulled apart; in the other, where a bone suture had been done in addition, the nail broke after five months.

On the contrary, results are very good if the nail is reinforced by a small tibial graft which, in addition to providing fixation, supplies osteogenetic material. The nail is introduced from the olecranon fossa and directed upward. The graft is fixed by screws,

TABLE VI

NON-UNION OF THE TIBIA WITHOUT BONE DEFECT

Operative Method	No. of Operations	Consolidations			Failures	Average Period before Union Was Obtained (*Months*)
		Normal	Delayed or with Complications	Per cent.		
Metallic fixation						
Plate	4	4		100		5
Nail	2	1		50	1	
Bolt or screws	2	2		100		3
Graft						
Sliding	12	7	3	83	2	6
From opposite side	6	6		100		4
Iliac	3	3		100		6
Küntscher nail and graft	1	1		100		5
Totals						
Operations	30	24	3	90	3	
Cases	28	25	2	96	1	

driven alternately on each side of the nail. The arm may be removed from the cast at the end of the first month and active exercise resumed. This method was successful in the eight cases in which it was used.

Non-Union of the Forearm

In the forearm, the author believes that the tibial graft fixed by screws is the best method. The nail is useful only when a tibial graft cannot be employed, in multiple fractures, or in fracture of the ulna at a high level, where accurate fixation of a graft would be difficult.

In this series union was obtained in all cases, with the exception that, in one case of non-union of both bones of the forearm, one bone remained ununited after operation. Of these thirty-four cases, eighteen had large bone defects (Table IV). A proper technique always gives good results in non-union of the upper extremity, even when large bone defects are present.

LOWER EXTREMITY

In the lower extremity, the difficulties and dangers encountered in non-union of the femur or tibia depend largely upon the presence and the importance of the bone defect. Consideration will be given, first, to those cases in which the bone defect is either absent or moderate enough to allow the surgeon to put the fragments together without too great shortening of the limb; and, second, to those cases in which an important bone defect must be bridged.

FIG. 4-A

FIG. 4-B

Fig. 4-A: April 12, 1946. Non-union of femoral shaft of one year's duration.
Fig. 4-B: May 7, 1947. Union five months after nailing and application of a sliding graft.

Non-Union without Important Bone Defect

1. *Femur:* When the bone defect is less than four centimeters, it is better to bring the fragments together. When overriding of the fragments exists, one must not resect the bone ends more than the minimum necessary to perform an end-to-end reduction; this is important, not only to avoid unnecessary shortening of the limb, but also to secure strong pressure of the bone ends on one another.

In these cases, intramedullary nailing is the method of choice. In this series, it was applied in thirteen cases with almost uniform success (Table V).

After the bone ends have been exposed and freshened, a proper nail is introduced from below upward into the superior fragment, and brought out of the thigh by a small incision over the trochanter. Then the fragments are reduced and the nail is driven into the inferior fragment.

In the first cases treated, the soft parts were closed afterward, a plaster cast was applied and left on for one month, and the patient was allowed to walk with canes. In three instances, however, consolidation was delayed; and after five or six months the nail bent (one case) or broke (two cases). Therefore, we think it necessary in all cases to complement the nailing by a graft fixed with screws. In seven cases so treated, consolidation always occurred normally in two or three months, the patient being allowed to walk from the end of the first month.

2. *Tibia:* Except for a few oblique fractures, successfully treated by freshening the fragments and fixing with screws, all cases of non-union in the tibia were treated by grafting.

The inlay graft is preferred, for it provides good fixation, often without any metallic material. The graft may be taken from the same tibia (sliding graft) or from the opposite

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 110. December 10, 1945. Large bone defect of femur after war wound (11 centimeters of shortening).

Fig. 5-B: October 6, 1947. Union eight months after grafting with tibial and iliac grafts. The shortening has been reduced to 5 centimeters.

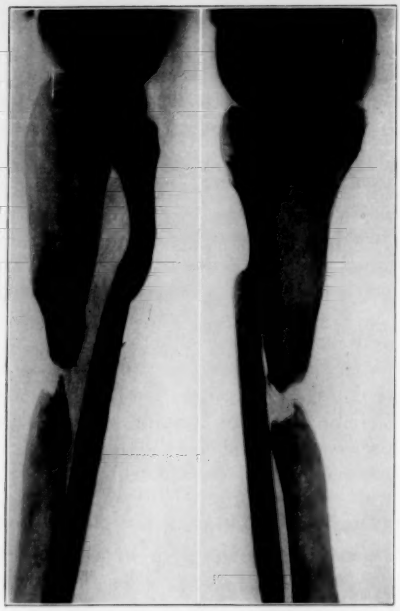

FIG. 6-A

FIG. 6-B

Fig. 6-A: September 17, 1946. Bone defect of tibia after war wound.
Fig. 6-B: May 31, 1947. Seven months after inlay tibial graft and cancellous bone grafts, union has occurred.

one. Notwithstanding its advantages, the sliding graft is not so safe as a graft from the opposite side. In three of twelve cases, a fracture of the graft occurred (Table VI), in one case while the plaster was being applied, immediately after the operation; in the other two, at the third or fourth month. On the other hand, six grafts from the opposite side resulted in six successes.

Large Bone Defects of the Lower Extremity

The treatment of such cases is much more hazardous, the greatest risk being the recurrent infection, always to be feared in these fractures with severe infection.

When the bone defect is very large, it is difficult to provide good fixation of the fragments. Therefore, a Küntscher nail was used, the defect around the nail being filled with iliac chips. This technique was used in five cases,—two femora with large bone defects

TABLE VII

NON-UNION OF THE FEMUR WITH LENGTHENING

Method Employed	Operative Results	Clinical Results
Küntscher nail plus iliac graft	Severe flare-up of infection. Deep, prolonged drainage until removal of nail and some of the graft.	
Case 28 (defect of 12 cm.)		Union in 22 months.
Case 31 (defect of 10 cm.)		Union in 14 months.
Tibial and iliac grafts	Uncomplicated. No flare-up of infection.	
Case 110 (defect of 11 cm.)		Union in 5 months. In sixth month, graft fractured under plaster spica. New graft united.

TABLE VIII

NON-UNION OF THE TIBIA WITH LARGE BONE DEFECT * (THIRTEEN CASES)

Operative Method	No. of Operations	Consolidations			Failures	Average Period before Union Was Obtained
		Normal	Delayed or with Complications	Per cent.		
Iliac graft						
Alone	1				1	Reoperation
Plus Küntscher nail	3	0	1**	33	2	1 amputation; 1 reoperation
Tibial graft						
Inlay	1		1**			
Sliding	1	1				8 months
Tibial graft plus iliac chips	8	7		88	1	6 months (1 in treatment)
Totals						
Operations	14	8	2	64	4	
Cases	12†	8	2	83	2	

* Defects varied from 3 to 12 centimeters, averaging 8 centimeters.

** Iliac graft added.

† One patient still under treatment.

(10 centimeters and 12 centimeters) and three tibiae. The results were not satisfactory (Table VII). One of the femora is now strong and free from infection; in the other a little sinus is still present, but there is fair callus; one of the tibiae has united. All five cases, however, showed very serious recurrent infection; all or part of their grafts were eliminated, and suppuration ceased only after removal of the nail. In two of the tibiae the result was a complete failure.

Therefore, we have now given up this technique and we always use a very long, wide tibial graft. This graft is inlaid in the fragments; the pieces of bone removed from the fragments are laid in the bone defect; and iliac chips are inserted in every free space. This method was successful in eight cases out of nine,—namely, in one femur and in seven of eight tibiae (Table VIII).

CONCLUSIONS

1. The *intramedullary nail* provides an excellent method of fixation for certain cases of non-union of the long bones. Its advantages for the femur and humerus are particularly striking; it reduces the time of immobilization in a cast to one month, and affords early rehabilitation of the muscles and joints. This is very important, as these patients have already been confined to bed for many months. However, the Küntscher nail must be discarded in all cases with previous deep infection, because of the risk of recurrent infection, as well as in those cases in which a large bone defect is present, especially at the femur or tibia. In addition, it must always be combined with a bone graft, firmly fixed to the fragments by screws.

2. The *tibial graft* alone is the best method for the tibia (inlay graft) and for the forearm (onlay graft). It must be fixed very firmly. If the onlay method is employed, screws are the best means of fixation (Tables IX and X).

3. The *cancellous bone* taken from the iliac crest is the best material to fill bone defects,

TABLE IX

NON-UNION WITHOUT BONE DEFECT

Method Employed	Humerus		Radius and Ulna		Femur		Tibia		Total	
	No.	Per cent. of Union	No.	Per cent. of Union	No.	Per cent. of Union	No.	Per cent. of Union	No.	Per cent. of Union
Nail alone	4	50	9	78	10	70	2	50	25	68
Graft alone	18	72	35	91	3	100	21	80	77	84
Nail and graft	8	100	4	100	3	100	1	100	16	100
Totals	30		48		16		24		118	

TABLE X

BONE DEFECTS

Method Employed	Humerus		Forearm		Femur		Tibia		Total	
	No.	Per cent. of Union	No.	Per cent. of Union	No.	Per cent. of Union	No.	Per cent. of Union	No.	Per cent. of Union
Nail plus cancellous bone	2	100			2	50	3	0	7	75
Tibial graft plus cancellous bone	3	100	11	100	2	100	8	88	24	96
Totals	5		11		4		11		31	

if the fragments are firmly fixed either by a tibial graft (for the tibia or femur) or by an intramedullary nail (for the humerus).

In all cases, the bones must be surrounded by healthy soft tissue, made possible by the excision of the fibrous tissue. This tissue must be replaced, where superficial bones are concerned, by a pedicled skin graft made in a preliminary stage. In the case of deep-lying bones, replacement is made in the same stage, by approximating the adjacent muscle tissue.

TUBERCULOSIS OF THE SPINE

An Analysis of Cases Treated Surgically*

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This study is based upon 177 consecutive cases of Pott's disease, treated surgically at Sea View Hospital during the six-year period from 1940 to 1945, inclusive. Its primary purpose was to examine the factors affecting the hospital mortality rate in this condition. Only those cases are included in the series in which at least part of the surgery had been done in this institution. Excluded are those cases which were deemed inoperable; those in which the patients refused surgery; and those in which complete surgery had been done at other institutions, and the patients were transferred to Sea View Hospital for convalescent or terminal care.

INCIDENCE OF POTT'S DISEASE

Of the 12,835 tuberculous patients treated at Sea View Hospital during the period covered by this study, only 417 had Pott's disease,—an incidence of 3.2 per cent. This percentage is well below that recorded in the literature. The generally accepted explanation for this reduction in percentage of spine lesions is the gradual disappearance of bovine tuberculosis. Auerbach[1] claims that osseous lesions are related to the primary complex. Due to improved treatment of progressive primary pulmonary tuberculosis, he believes that the period of possible metastasis is shortened and the percentage of bone lesions is reduced[2].

THE HOSPITAL MORTALITY RATE

The mortality rate for the 417 cases of Pott's disease was 55.8 per cent. (233 patients died). Of the 177 patients operated upon, 66 (37.3 per cent.) died; among the 240 patients not operated upon, there were 167 deaths (69.6 per cent.).

Of the patients with all forms of tuberculosis treated at Sea View Hospital, 4,114 died and 8,721 were discharged, the general mortality rate being 32.1 per cent. The mortality rate for the patients operated upon in our series is only 5.2 per cent. higher than this. If we consider that the patients operated upon had more extensive involvement than the average, and, if we contrast the percentages of mortality of those operated upon and those not operated upon, the favorable influence of surgery becomes evident.

FACTORS INFLUENCING THE MORTALITY RATE

Age

The incidence and the death rate in each decade (Charts 1 and 2) are in accord with Cleveland's figures, except that we found the highest mortality rate to be in the sixth decade, whereas it was in the third decade in Cleveland's series. However, like Cleveland, we found that the very young patients did best of all, with a mortality rate of only 14.3 per cent. This figure is offered for the consideration of those who have accepted early fusion as the treatment of choice in Pott's disease in adults, but still hesitate to employ the same method in children. The deceleration of deformity and the increase in the child's life span, provided by surgery, are truly astonishing. Of twenty-four children under thirteen years of age who survived, the average postoperative stay in the Hospital was fifteen and one-half months. Of fifteen children not operated upon, the average hospital

* Read at the Orthopaedic Section of the New York Academy of Medicine, April 1948.

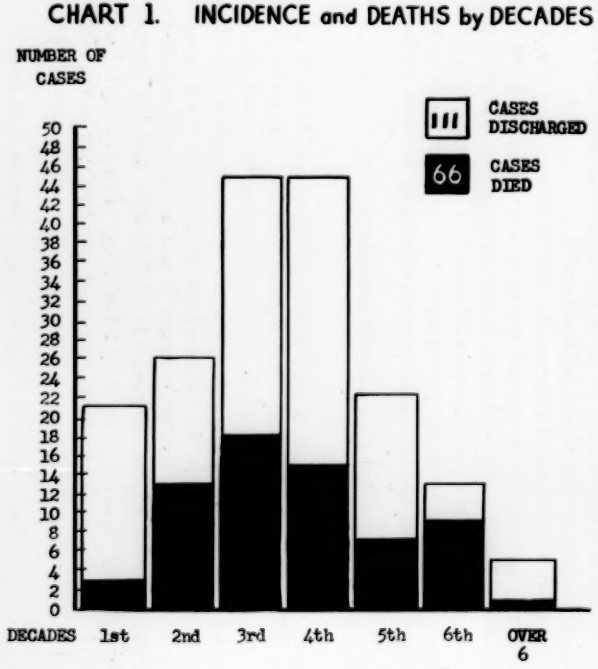

CHART 1

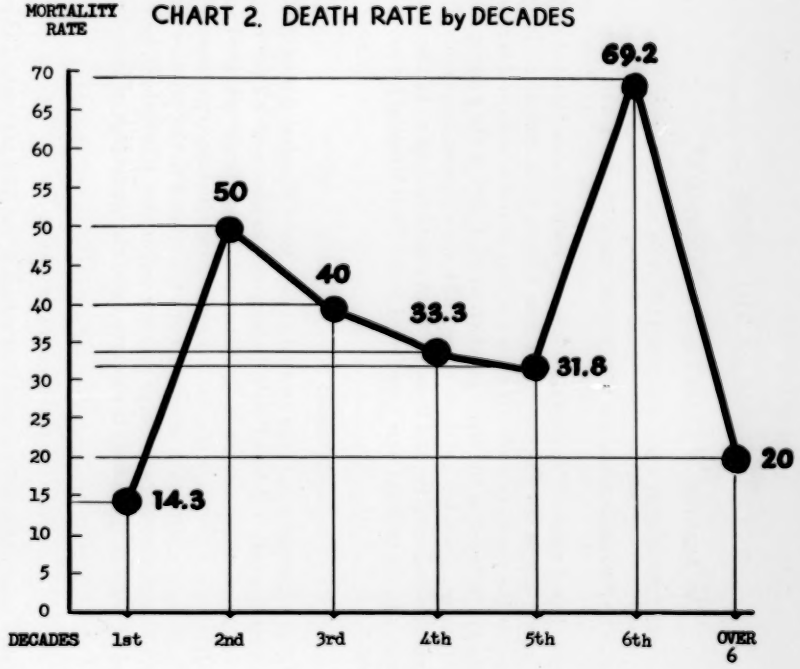

CHART 2

stay in the six-year period was twenty-six and one-half months. No child who was not operated upon recovered sufficiently to be discharged.

Sex

One hundred and eleven of the patients were males and sixty-six were females,—a preponderance of the male sex which has been observed before. Forty-five of the male patients died and twenty-one of the female patients, which gives a higher mortality rate (40.5 per cent.) for the males, as compared to the females (31.8 per cent.).

Race

Members of the negro race show a definite susceptibility to tuberculosis of the spine. While negroes represented only 38.7 per cent. of the total admissions to Sea View Hospital, they constituted 221 (53.1 per cent.) of the patients with Pott's disease. However, only 39.4 per cent. of the negroes who had had adequate surgery died (37 of 94 cases), as compared to 34.6 per cent. of the white patients (28 of 81 cases). In other words, with comparable surgical care, the negro with tuberculosis of the spine has a chance of survival almost equal to that of the white man.

Area of Spine Involved

The distribution of tuberculous lesions of the spine in this series is in agreement with the pattern reported by others. In 82.5 per cent. of our patients, the lesions were present in the lower thoracic, thoracolumbar, and lumbar regions (Chart 3). No attempt was made to list the number of vertebrae involved in each case. The exact extent of the disease can only rarely be determined by clinical or roentgenographic study. In twenty-nine cases, more than one of the seven charted areas were diseased; in five of these, more than two areas were affected; and in two instances, the entire spine was involved. The more widespread involvement did not seem to affect adversely the mortality figure among the

CHART 3. INCIDENCE and DEATHS by SPINE AREAS INVOLVED

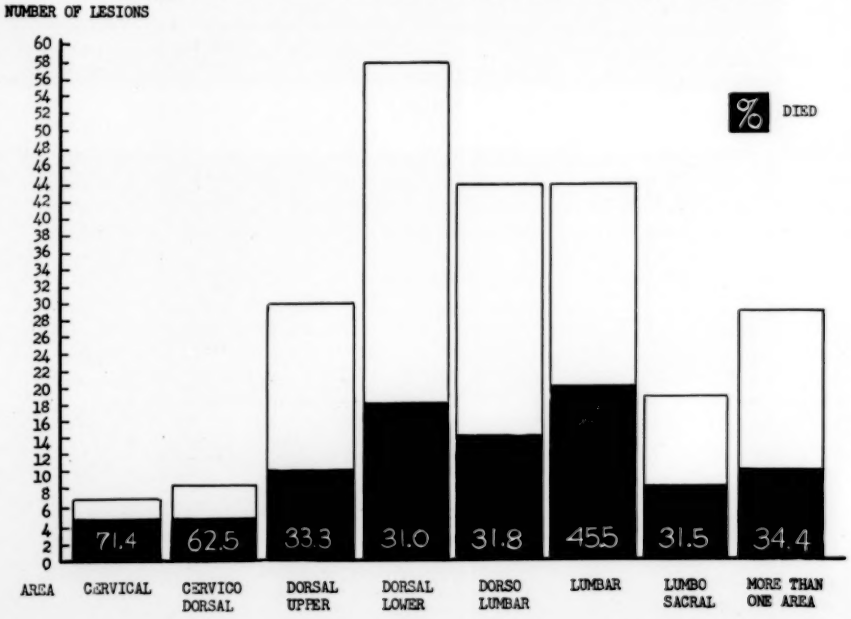

CHART 3

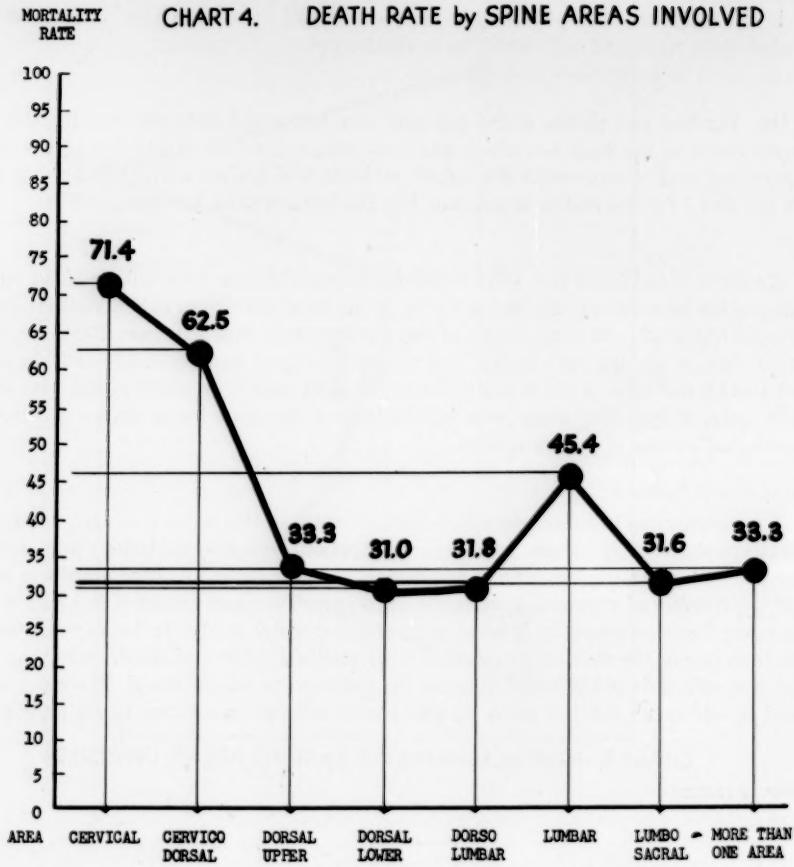

CHART 4

surgically treated patients. This observation has also been made by Girdlestone. However, unlike Cleveland or Girdlestone, the authors found that disease in the upper (cervical) portion of the vertebral column carried the highest mortality rate (71.4 per cent.); the lowest rate (31 per cent.) was found in disease of the lower thoracic area (Chart 4).

TABLE I

PATIENTS WITH NEURAL-ARCH DISEASE *

Area of Involvement	Number Died	Number Discharged
Cervicothoracic	1	
Thoracic		
Upper	4	
Lower	7	3
Thoracolumbar	7	2
Lumbar	5	
Lumbosacral		1

* In 22 of 66 patients who died: 33.3% incidence.
In 6 of 111 cases discharged: 5.4% incidence.

FIG. 1

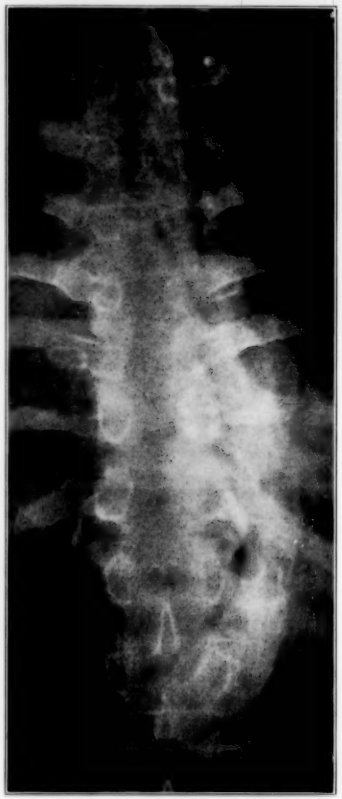

FIG. 2-A

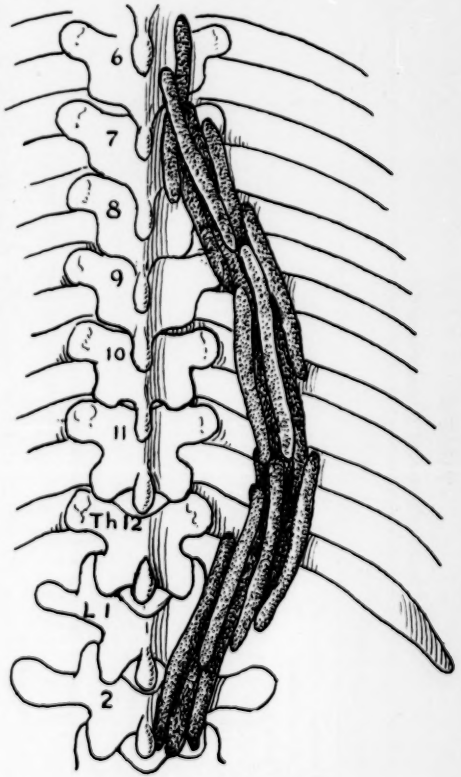

FIG. 2-B

Fig. 1: Neural-arch disease, such as is evident in this case, is rarely shown by roentgenogram, but may be diagnosed clinically.
Figs. 2-A and 2-B: Where sinuses exist in the mid-line and both right and left sides of the neural arches are involved, a circumduction fusion may be done from the sound spinous processes above. The neural arch can be built out around the ribs and back to the sound spinous processes of the neural arch below.

TABLE II

SINUSES IN SPINAL TUBERCULOSIS *

Area of Involvement	Number of Cases
Cervical	1
Cervicothoracic	2
Thoracic	
Upper	7
Lower	15
Thoracolumbar	25
Lumbar	13
Lumbosacral	14
More than one area	10

* In 45 of 66 patients who died: 68.2% incidence.
In 24 of 111 patients discharged: 21.6% incidence.

Neural-Arch Involvement

It is generally accepted that the posterior elements (neural arches), or so-called small parts, of the vertebrae are seldom involved. Although disease in this location is considered a serious problem, a review of the literature has failed to reveal any studies on this subject.

The surgical importance of such a lesion is obvious. Fusion must be attempted in this region and, if tuberculosis is present, the surgeon works in an infected field, on bone already diseased. Statistics from this series of cases prove the seriousness of such involvement (Table I). The neural arches were involved in twenty-eight of the patients,—an incidence of 15.8 per cent. Of these, twenty-two died,—a mortality rate of 78.6 per cent.

Fortunately, clinical evidence of such involvement sometimes exists preoperatively, as shown by the presence of swelling, abscess formation, or sinus near the mid-line. Often it is detected only at operation. Rarely is it demonstrable by roentgenogram (Fig. 1). It is only when the disease process is well advanced that roentgenographic evidence of involvement of the neural arches can be ascertained definitely.

While neural-arch involvement necessitates a guarded prognosis, 21.4 per cent. of the patients in this series were discharged on a moderately active regimen, as determined by an average follow-up of three and one-half years. It has been the policy of this Service to proceed with fusion when neural-arch disease is not discovered until after surgery has been begun. If clinical evidence of such disease is discovered before operation, and if the tuberculous process is confined to one side, a hemifusion is attempted on the opposite side. The skin incision in such cases is made well away from the mid-line. For the occasional

TABLE III

POSITIVE SPUTUM AND SPINAL TUBERCULOSIS *

Area of Involvement	Number of Cases
Cervical	1
Thoracic	
Upper	5
Lower	14
Thoracolumbar	8
Lumbar	16
Lumbosacral	4
More than one area	5

* In 15 of 66 patients who died: 22.7% incidence.
In 28 of 111 cases discharged: 25.0% incidence.

TABLE IV

OTHER SKELETAL FOCI OF INFECTION *

Foci	Died	Discharged	Total
Elbow	10	3	13
Knee	7	3	10
Foot and ankle	4	5	9
Sternum	4	3	7
Hip	2	4	6
Shoulder	4	1	5
Wrist	2	3	5
Fingers	3	1	4
Sternoclavicular joint	3	0	3
More than one focus	11	1	12

* In 29 of 66 patients who died: 43.9% incidence.
In 22 of 111 cases discharged: 19.8% incidence.

case in which neural-arch involvement is bilateral, yet the patient's general condition remains good, a variant of the fusion procedure has been devised. Hemifusion with iliac strips is done in stages, building from sound spinous and transverse processes above the tuberculous area outward onto the ribs (Figs. 2-A and 2-B). This reconstruction is carried downward onto the ribs, and then inward to the spinous processes below the diseased area. Such a fusion can be successful even in the presence of mid-line sinuses.

Sinuses

In sixty-nine of the patients operated upon (38.9 per cent.), mixed-infection tuberculous sinus tracts were present. Of this group, forty-five patients (65.2 per cent.) died during their hospital stay. Thus, the presence of a sinus is a grave finding. In this series there was no preponderance of sinuses from any area. The distribution closely paralleled that of the tuberculous lesion, with the greatest number appearing in the thoracolumbar area (Table II). As in fractures, compounding the lesion adds great hazard. Healing may occur and may be permanent, but a potential explosive element remains. When the sinus persists, serious complication is to be expected. Streptomycin seems to be changing the picture, but the study of its effectiveness is not yet complete.

Pulmonary Tuberculosis

There was a surprising lack of correlation in this series between a history of active pulmonary tuberculosis with positive sputum and the mortality rate. Of the 177 patients operated upon, forty-three (24.3 per cent.) had had active pulmonary tuberculosis with

TABLE V

NON-SKELETAL EXTRAPULMONARY FOCI *

Source of Infection	Died	Discharged	Total
Genito-urinary	11	7	18
Cervical adenitis	6	3	9
Gastro-intestinal	8	0	8
Soft-tissue foci in extremities	1	3	4
Peritonitis	2	1	3
Larynx	1	1	2
More than one area	2	2	4

* In 26 of 66 patients who died: 39.4% incidence.
In 13 of 111 cases discharged: 11.7% incidence.

positive sputa or gastric washings (Table III). The mortality rate in this group was 34.9 per cent., which is 2.8 per cent. more than that for the series as a whole.

Cleveland believed that joint tuberculosis in patients with pulmonary lesions and positive sputa had an unfavorable prognosis exceeded only by metastatic spread to other organs. The success now achieved must be credited to the great advances in control of pulmonary tuberculosis.

Other Bones as Foci of Infection

In fifty-one (28.8 per cent.) of the cases, the spine was only one of several bone foci present. Of these patients, twenty-nine (56.9 per cent.) died. There were twelve patients with more than one extraspinal bone focus; and of these, only one survived,—a mortality rate of 91.7 per cent. The survivor was a young woman in excellent general condition with involvement of only the ankle and talonavicular joint on the same side. Fusion was successful in both of these joints, as well as in the spine. A ten-year follow-up on normal activities was made in this case.

An unexpected finding was the distribution of the extraskeletal bone foci. The site most frequently involved was the elbow; next in order of occurrence were the knee, foot and ankle, sternum, and hip (Table IV).

Non-Skeletal Extrapulmonary Foci

Of thirty-nine patients with other extrapulmonary foci, twenty-six or 66.7 per cent. died (Table V). This figure bears out Cleveland's contention that patients with complicating organic foci have a poor prognosis. The genito-urinary tract was affected in eighteen patients (10 per cent.). Other writers [1, 6] have found higher proportions.

Amyloid Disease

Positive proof of amyloidosis was found in twenty-seven patients (15.2 per cent.). All but one died,—a mortality rate of 96.3 per cent. The one patient who was discharged had repeated 100 per cent. Congo-red absorption. She disappeared after a follow-up of two and one-half years, apparently well, but on limited activity.

SUMMARY

1. In tuberculosis of the neural arch the prognosis is poor, but fusion is often successful.

2. While negroes appear more susceptible to tuberculosis of the spine than white patients, they have an equal chance for recovery when offered adequate surgery and care.

3. Children with Pott's disease progressed unfavorably under conservative care at Sea View Hospital, but presented the greatest and most rapid recovery rate in the whole series when fusion was done.

4. Pulmonary tuberculosis, when controlled by modern methods, does not appear to affect the prognosis in the patients operated upon.

5. Amyloid disease accompanying tuberculosis of the spine is practically always fatal.

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SPONDYLITIS, PATHOLOGICAL OSSIFICATION, AND CALCIFICATION ASSOCIATED WITH SPINAL-CORD INJURY *

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The many problems of injury to the spinal cord have been the subject of recent investigation. The bones, ligaments, soft tissues, and joints may be affected by permanent damage to the spinal cord. Neuropathic joint changes were commented on as early as 1831 by Mitchell, and in 1868 by Charcot. Calcifications and ossifications in the soft tissues, chiefly about the hips, have been noted by many writers, including Voss, Brailsford, Soule, and Heilbrun and Kuhn, who also studied erosive bone changes about the trochanters. This paper emphasizes another phase of abnormal bone and joint physiology,—a spondylitis similar in many respects to the rheumatoid type, with frequent involvement of the diarthrodial joints. The relationship of these changes to spinal-cord injury prompted this study.

Thirty-five cases of injury to the spinal cord were studied. Of this number, twenty-four patients had complete transverse lesions; six showed partial lesions above the first lumbar segment; and five had lesions of the cauda equina. The ages of the patients varied from eighteen to fifty-five, with an average of twenty-eight years. Only four patients were over forty years of age. The average time from injury until admission to this Hospital was seventeen months, ranging from two to seventy-six months. The average hospital stay until discharge, transfer to another center, or death, was eight months, ranging from one to thirty-four months.

LABORATORY FINDINGS

Twenty cases of complete lesions of the spinal cord were selected for determination of the blood-serum calcium and phosphorus, blood chlorides, serum proteins, and the qualitative urinary-calcium excretion (by the Sulkowitch test). Serum acid and alkaline phosphatase were determined in eight cases (by the King-Armstrong method). The acid phosphatase was within normal limits and the alkaline phosphatase was elevated to twenty-three units in only one instance, associated with hepatitis and jaundice. Blood-calcium values ranged from 7 to 12.2 milligrams per 100 cubic centimeters, with an average of 10.4. Blood-phosphorus values averaged 3.5 milligrams per 100 cubic centimeters, with a range of 1.9 to 4.3. The Sulkowitch test showed one to four plus excretion in all cases except two. The blood chlorides were below 400 milligrams per 100 cubic centimeters in nine of these patients. The serum proteins averaged 6.6 grams per 100 cubic centimeters, with a range from 4.8 to 7.8.

ROENTGENOGRAPHIC FINDINGS

Roentgenographic survey included the vertebral column, pelvis, and the hip region. (Discussion of the fracture or site of injury is intentionally omitted.) The bone changes and the level of the injury to the cord were correlated, and two groups were established: Group A included lesions below the first lumbar vertebra and all partial lesions, irrespective of site, since the roentgenographic findings in these two types revealed little essential difference; Group B included all complete transverse lesions above the first lumbar segment.

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FIG. 1-A

Soft-tissue ossifications and calcifications.

Fig. 1-A: January 18, 1946. A white male, twenty-six years old, was injured in August 1943, by a fall from a three-story building, and suffered a transverse lesion of the cervical cord. Oblique cysto-urethrogram demonstrates fibrositic calcification of the soft tissue of the buttock. Apophyseal-joint involvement and osteoporosis are also seen.

FIG. 1-B

Fig. 1-B: January 21, 1946. A white male, forty-two years old, was struck on the back in August 1943. The lesion was at the level of the first lumbar vertebra. Periosteal new-bone formation can be seen, extending upward from the region of the greater trochanter. The upper portion has the appearance of solid bone. Some increased density of the acetabular rim is present, although the joint space is not involved.

Fig. 1-C: May 21, 1945. A white male, twenty-five years old, was injured in May 1943, by a bullet which severed the spinal cord at the level of the third thoracic vertebra. Periarticular calcific changes about both hips are seen, with capsular involvement on the right. There is a bony exostosis, arising from the anterior margin on the left. Small areas of calcific deposits are seen in the soft tissues. There is a marked increase in the density of the pelvic bones, and the sacro-iliac joints are almost completely obliterated.

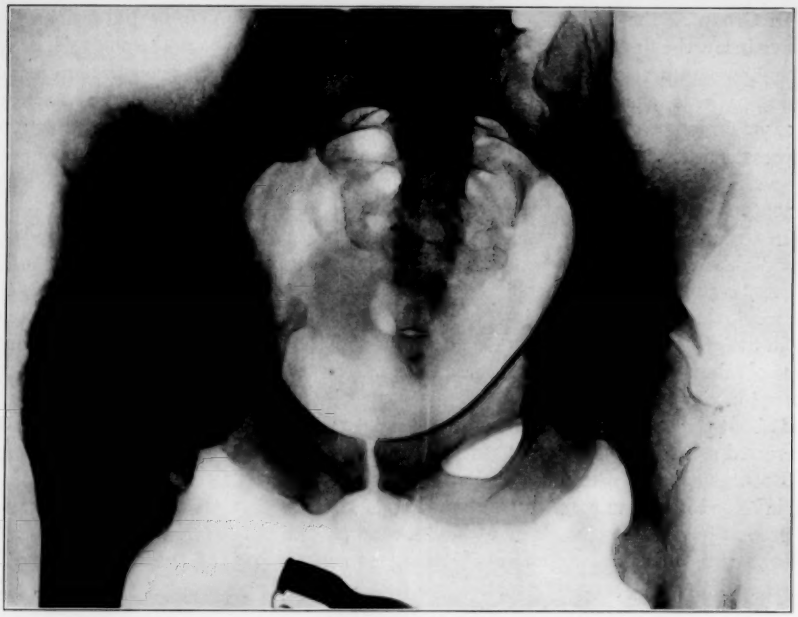

FIG. 1-C

FIG. 1-D

Fig. 1-D: June 27, 1945. A negro male, twenty-eight years old, had a complete transverse lesion at the ninth thoracic segment, secondary to a bullet wound. Periosteal bone formation is seen about the region of the left hip. The bones of the pelvic girdle have a sclerotic appearance, and there is obliteration of the sacro-iliac joints. Lacy and bizarre arrangement of periosteal new bone is present. There are fibrositic calcific deposits about the region of the right hip.

In Group A, the findings were not significant. There were six partial lesions above and five below the first lumbar vertebra. One case was excluded from the analysis, because no roentgenogram was obtained of the lumbar spine or pelvis. In seven of ten of the remaining patients, changes were evident in the sacro-iliac joint, manifested by narrowing or partial fusion. Otherwise, the pelvis was negative in four patients, and osteoporosis was present in six. Fusion of the apophyseal joints occurred in two patients. The lumbar spine was otherwise negative in five and osteoporosis was present in five patients. No other ligamentous or soft-tissue changes were observed in this group.

In Group B, the findings were more striking, and represented a more advanced stage of the disease process. There were sixteen low-thoracic lesions, five upper-thoracic lesions, and three cervical lesions. The pelvis was negative in two cases, with osteoporosis in fourteen, marked sclerotic changes in only three, and a combination of sclerosis and osteoporosis in five. Of primary interest were the sacro-iliac joints, in all but three of which some degree of sclerosis was manifest, varying from partial to complete fusion. Complete fusion occurred in eight patients, in four of whom it was bilateral. Some degree of sclerosis was noted about the acetabular margins. Other findings included lacy periostitis of both ischia, a narrowed symphysis pubis, and streaky calcifications in the buttocks.

Roentgenographic findings in the lumbar spine showed that the apophyseal joints were involved in fifteen cases, with a varying degree of fusion. Osteoporosis of the bodies was present in twelve, sclerosis in six, and a combination of the two in four patients. The bodies were negative in two patients. Rather marked sclerosis of the bodies of the fifth lumbar and the first sacral vertebrae was present in nine patients. Calcification of the paraspinal ligaments occurred in only two patients.

Of particular interest were the proliferative bone changes and soft-tissue calcifications about the hip joints and the upper portion of the femur, seen to a varying degree in seven patients in this series. There was no definite period of time between the trauma and the roentgenographic manifestations, although most of these patients were seen one to two years after injury.

COMMENT

A variety of bone lesions occur in the paraplegic patient (Figs. 1-A through 1-D). The soft-tissue ossifications and calcifications about the hip are of frequent occurrence, but they follow no similar pattern. Thus, exostoses may arise from the acetabular margin, or periosteal new-bone formation may be present. New-bone formation or calcification may occur in the muscles or fascia. The appearance may be like that of solid dense bone or it may have a striated appearance. Proliferative bone changes may occur in the tendons or joint capsules, and, in the latter, may lead to ankylosis. The joint space, however, is usually uninvolved.

No evidence of the neuro-arthropathies was seen in this series, probably because of the relative infrequency of weight-bearing and increased recumbency. Soule stated that the changes are most prominent about the tibial collateral ligament. He observed no ossifications anterior or posterior to the knees in his series. Heilbrun and Kuhn described the erosive bone changes in the region of the greater trochanter, secondary to decubitus ulcers, as "first, erosive changes leading to loss of the normal contour of the trochanters with flattening, followed by reshaping or molding, and later repair of the eroded surface with formation of an abnormal contour by proliferative or exuberant bone. . . . Pathologically this is evidenced by a subacute and chronic infection of the tissue overlying the bone, with extension to the superficial layers of bone. This leads to resorption of the cortex and underlying trabeculae. The bone marrow is replaced by fibrovascular tissue which accompanies the low-grade inflammatory process."

The involvement of the sacro-iliac and apophyseal joints and the spinal ligaments is merely one phase of the over-all disease process. The similarity between this form of

spondylitis and rheumatoid spondylitis is evidenced by involvement of the small posterior intervertebral articulations and the sacro-iliac articulations, the atrophy of the bodies, and the calcifications of the interspinal ligaments. Certain differences are evident. Despite the level of the cord injury, no instance was seen of involvement above the lumbar spine. Although osteoporosis was the predominant finding, it may be accompanied by densification. The paraspinal ligaments are more commonly involved in rheumatoid spondylitis.

The changes observed in this group of paraplegic patients include: exostoses, diarthrodial-joint and ligament changes, massive soft-tissue ossifications and pathological deposits of calcium, and sclerosis and osteoporosis of the pelvis and vertebrae. In these patients, the importance of the neurotrophic lesion is apparent. Eloesser and Repetto have added to the knowledge of the pathogenesis of the neurotrophic joint. By animal experimentation they were able to prove that, in addition to loss of joint sensibility, repeated traumata were necessary to produce the typical joint changes. The neurotrophic lesion and repeated traumata play an important part in the production of the extensive soft-tissue calcifications or ossifications. Whether or not the mechanism of pathological calcification is due to disturbance in fat metabolism, changes in the pH of tissues, phosphatase activity, secondary hyperparathyroidism, or circulatory changes, or to a combination of these factors, is not definitely known.

Klotz demonstrated antecedent fat changes in the affected areas with insoluble compounds replacing soluble ones, particularly with an excess of calcium. Robison emphasized the importance of phosphatase in pathological calcification. He found that this enzyme was richest in ossifying cartilage and, to a lesser degree, in the kidneys. In affected tissues there is hydrolysis of the ester and liberation of inorganic phosphate. The increased concentration of phosphate results in the precipitation of carbonates. Gomori, however, has demonstrated that calcification of hyalinized connective tissues occurs without any phosphatase activity, but that living or recently necrosed tissue seems to involve phosphatase activity.

Wells believed that, in areas of tissue degeneration, deposition of calcium salts is dependent upon increased alkalinity or decreased carbon dioxide. He suggested that calcium salts are held in solution by proteins, either as carbonate or phosphate or as calcium-ion protein compounds, or both. This delicate balance is capable of being overthrown by alkalinity, changes in protein or carbon dioxide, or changes in the quantity or composition of the calcium salts. Vaughan and his associates stated that there is a tendency for precipitation to occur with marked changes in the pH of the media, or when increased phosphatase is present. Precipitation with normal blood levels may take place from non-colloidal ionic solutions. When hypercalcaemia is present, precipitation occurs from colloidal suspension of calcium-phosphate-protein complex. In renal disease, Schmidt pointed out that the increased albumin and phosphate excretion affected the calcium balance. These substances ordinarily act as buffers to keep calcium in solution. With chronic renal disease, the production of secondary hyperparathyroidism is another possible etiological factor. Pappenheimer demonstrated hyperplasia of the parathyroids in nephritic conditions. He showed that reduction of renal tissue in young rats resulted in an increased volume of the parathyroids. In addition, when these rats were placed on a low-calcium diet, rachitic changes occurred in the bones. With a moderate-calcium diet, the changes were in the direction of osteitis fibrosa. Soffer and Cohn, in discussing secondary hyperparathyroidism, found that such cases were not characteristic. There may be hyperplastic glands with or without bone changes, or bone and chemical changes with histologically normal parathyroid glands. The demand for calcium apparently is increased, although the exact mechanism is uncertain.

From a pathological standpoint, the explanations advanced by Leriche and Policard, and Watson Jones and Roberts, based on the importance of circulatory disturbances, offer a reasonable explanation for the multiple changes observed in these individuals. Thus, hy-

FIG. 2-A Sacro-iliac and apophyseal-joint changes. FIG. 2-B

Fig. 2-A: *Early changes.* February 18, 1946. This white male, nineteen years old, was injured in April 1944, by a twenty-foot fall, and suffered complete transection of the spinal cord at the seventh thoracic segment. Pyelocysto-urethrogram illustrates narrowing of the sacro-iliac joint, with haziness and increased density surround-

FIG. 2-C

FIG. 2-D

Fig. 2-A (*Continued*) ing the joint margin. Sclerotic changes of the apophyseal joints are also present, with complete obliteration of the joint between the fourth and fifth lumbar vertebrae. Scattered areas of increased density of the vertebrae are seen.

Fig. 2-B: *Moderately-advanced changes.* November 28, 1945. This white male, twenty-four years old, was struck on the back by a falling tree in December 1943, and suffered a complete transverse lesion at the level of the twelfth thoracic vertebra. Intravenous pyelogram reveals further narrowing and increased density. There is bony fusion of the upper half of the left sacro-iliac joint. This area assumes the trabecular pattern of bone. The apophyseal joints show obliteration and narrowing.

Fig. 2-C: *Far-advanced changes.* May 13, 1946. A white male, forty-six years old, suffered a complete lesion at the level of the tenth thoracic vertebra, as the result of an automobile accident in November 1943. A roentgenogram shows complete obliteration of the sacro-iliac joints. Osteosclerotic changes of the pelvis and osteoporosis of the femur are present.

Fig. 2-D: *Apophyseal-joint changes.* January 22, 1946. A white male, twenty-three years old, was injured in May 1944, by a shell fragment, and suffered a complete lesion at the level of the eleventh thoracic vertebra. An oblique cystogram demonstrates narrowing of the apophyseal joint between the fourth and fifth lumbar vertebrae, with irregularity of the joint margin. Coarse trabeculations are seen.

peraemia of bone is followed by decalcification; diminished circulation, by osteosclerosis; and loss of blood supply, by necrosis. Pathological calcification can occur in any mesenchymal tissue of low metabolism when vascularity is further reduced by trauma and infection. Bone may form in any region where there are fibroblasts, an excess of calcium, and an adequate blood supply. Adult tissue which can be differentiated into primitive mesenchyma may be rebuilt as bone with an excess of calcium.

The explanation of the early occurrence of osteoporosis is not difficult. Recumbency and immobilization result in demineralization of bone and hypercalcinuria. Osteoporosis is associated with decreased bone formation and underactivity of osteoblasts. Blood calcium, phosphorus, and phosphatase levels are normal. The loss of protein from decubitus ulcers, with subsequent failure to supply material for a matrix, is another factor in the production of osteoporosis. Part of the depression of bone formation may be due to alteration in function of the adrenal cortex or malnutrition.

In the spondylitic form of the disease, the roentgenographic findings reflect the pathological processes occurring in the various portions of the body mentioned. The changes are more pronounced in complete lesions above the first lumbar segment of the cord. Normally, physiological changes occur with advancing age. Sashin has shown that sacro-iliac changes are slight in individuals under thirty years of age. In those between thirty and sixty years of age, gross changes are found in 91 per cent. of males and 77 per cent. of females. The changes that occur in the sacro-iliac joints in spondylitis are not only more common, but also more diagnostic, than the changes which occur elsewhere. In most cases of spondylitis, there may be simultaneous involvement of the sacro-iliac and apophyseal joints and spinal ligaments, or involvement of the sacro-iliac joints alone. Varying degrees of involvement were found in twenty-nine of our patients, an incidence of 85 per cent. (Figs. 2-A through 2-D). The earlier changes observed were haziness of the margins, with the joint space becoming less distinct; later, there was narrowing of the joint outline and proliferation and densification along the margins, with scattered areas of fusion. In far-advanced cases, there was more complete fusion, with obliteration of the joint in many instances. As complete fusion occurred, there was continuity of bone between the sacrum and ilium, and trabeculations were established across these joints. The changes in the apophyseal joints, which occurred in 50 per cent. of the patients in this group, were similar to those in the sacro-iliac joints, although not so frequent. The paraspinal and longitudinal ligaments were not involved, as a rule, and calcification of the paraspinal ligaments occurred in only two cases. Osteoporosis of the pelvis and lumbar spine was the most common finding, although at times it was associated with sclerosing changes. In a few instances, sclerosis predominated.

The subjective complaints and objective findings in relation to these abnormalities of bone were not striking, because of involvement of the spinal cord. A few of these patients, with far-advanced hip changes, were unable to sit in a wheel chair, because of partial ankylosis. There was loss of the normal lumbar curve.

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MYOSITIS OSSIFICANS IN PARAPLEGICS

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At the end of World War II, a large number of paraplegic patients had to be treated at the various paraplegic centers throughout the United States. As a result of excellent care, these patients are now living longer than the average patient of several years ago, and some are presenting unusual complications. The authors have compiled data concerning one of these complications, as well as meager material which has been culled from the literature.

Myositis ossificans was recognized more than two hundred years ago. Until after World War I, however, practically nothing was written about the occurrence of this disease in transverse lesions of the spinal cord. The principal reports in the literature have been recorded by French neurologists. After World War I, they followed a considerable number of these patients from an orthopaedic as well as from a neurological standpoint, and presented some of the earliest descriptions of myositis ossificans in the paraplegic patient.

In 1919, Dejerine, Ceillier, and Dejerine presented a paper to the *Société de Neurologie* of Paris on the anatomical and histological study of para-osteo-arthropathies in cord lesions. They stated that para-osteo-arthropathy has certain points of predilection. The first area is about the medial femoral condyle. Dense compact tissue is formed, which may be a single mass or may have an apparent extension along the femoral shaft. This diaphyseal extension, however, is a fine lacework of bone described as being "*soufflées*". Second, the condition is found about the hips, but never above the pelvis or below the knees. The incidence of this lesion was found by Dejerine and her co-workers to be 48.7 per cent. They also stated that the lesions make an early appearance and undergo rapid evolution to variable size. There was complete integrity of the articular skeleton, except in one case, in which they found this condition concomitant with evidence of osteo-arthritis. The type of tissue at the various sites of predilection was quite constant; they found no evidence of infection or hemorrhage in the area of calcification, nor was the calcification found in decubitus ulcers or scars.

Since 1919, many articles have been written on myositis ossificans resulting from trauma, but not in reference to cord lesions. Geldmacher, in 1925, wrote an article on the subject of myositis ossificans in cord lesions, which was referred to by Frejka in 1929 in his case study of progressive myositis ossificans. In 1943, Hanke, in Germany, wrote an article on myositis ossificans circumscripta neurotica in paraplegics following vertebral fracture. Stanger, in 1946, reported the complication in two cases of paraplegia. He describes this condition as ossification of the pelvifemoral muscles following fracture-dislocation of the thoracolumbar region of the spine, sustained in coal-mine accidents near Leeds, England. The ossification became evident six months after injury, but the masseuse had noted increased resistance to passive flexion at four months. One patient showed no other ossification. The other patient later had kidney calculi and some involvement of the knee joint.

Frejka, in his report of progressive myositis ossificans, mentions Geldmacher's study, in which the knee and hip joints were involved at a very early date after cord trauma. Para-articular bony layers appeared, "partly adjacent to the periosteum, partly lying free in soft parts". He reported that development was fully attained within eight months, and that the condition remained static thereafter. Frejka further states that: "The new bone formation is always primary. Neither hemorrhages, inflammatory changes, necroses, or new vessel formation have been observed."

These are the observations which have been made in the past on myositis ossificans in paraplegics; our observations have many points in common with them. The sites we have seen most frequently involved are the hips, the upper third of the thighs, and the knees. Involvement of the knee has not been frequent, but the ossifications seem to be similar in type to those described by Dejerine at the medial femoral condyle. The mass in the thigh is palpable and is usually very firm or hard and indurated. It is fixed and follows along a muscle group from the pelvis to the thigh, either anteriorly or medially. If the mass is large, the size of the thigh is increased. Hip motion is usually limited; however, in only one case thus far has surgery been necessary to free the hips, in order to permit the patient to be mobile in a wheel chair. The pelvis and lower extremities show marked osteoporosis and, with the severe spasms, the hip may be dislocated or the femoral neck fractured. Urinary calculi are often seen in these patients. In fact, the myositis ossificans is frequently an incidental finding on a "scout film" for kidney calculi.

Often these patients lie prone in bed for long periods of time, while plastic surgery is carried out on their decubitus ulcers, thus placing pressure continually on the anterior portion of the thighs. The patients are moved frequently by attendants, and they get in and out of wheel chairs, automobiles, bathtubs, and carts by themselves, putting traction and strain on soft parts of paralyzed, anaesthetic limbs. There is also the passive motion of physical therapy, combined with heat and massage, performed in a gentle yet manipulative manner. Some paraplegics have ossification in one area of predilection, but seldom in

all three areas of predilection. We have felt that the lesion appears as Dejerine and her associates describe, but we have not seen nearly so high an incidence (48.7 per cent.) as they report. In this institution there has been a continual turnover of patients, with the constant number remaining around 289 patients; yet we have never seen more than twelve cases of typical myositis ossificans during any three-month period.

Classification

The authors have accepted the classification of Noble, as quoted by Golden:

1. *Myositis Ossificans Progressiva*

This disease begins soon after birth and is characterized by congenital microdactylia, or at least by short first digits of the hands and feet. There is apparently a metamorphosis of muscle into bone, all of the skeletal muscles becoming involved progressively. Death may occur from involvement of the diaphragm and the abdominal muscles.

2. *Myositis Ossificans Circumscripta Resulting from Local Trauma*

This is called muscular osteomata and usually develops late in life, possibly due to occupational injury. The disease process is localized to one site of repeated injury,—for example, the adductor longus ("rider's bone") or the brachialis ("fencer's bone").

Another local ossification following a single trauma belongs in this group. History has been obtained of a severe contusion, a dislocation, or a tangential bullet wound to the bone. The condition may also develop in the muscles of the abdomen after surgery. This is the most common type of myositis ossificans and may become a surgical problem. The injury in this type is recent, but the pain seems to continue beyond the time that it would normally be present. In about three to five weeks, a deep-seated fixed swelling is palpable at the injury site, and roentgenograms reveal a calcium shadow in the region of the muscle. The swelling may extend down to bone and become attached. This type is often confused with sarcoma; but it follows a muscle pattern, never shows erosion of the bone shaft, and is parallel to the shaft.

3. *Myositis Ossificans Circumscripta without History of Trauma*

The condition is usually an incidental finding during examination of the patient or of his roentgenograms. This group includes the myositis ossificans circumscripta neurotica which is discussed in this paper and recorded by Geldmacher, Frejka, and Dejerine. It is a para-articular ossification, associated with cord lesions. Also included in this group are the tabetic osteo-arthropathies and the soft-tissue calcification which occur in these patients from very minor trauma, such as hypodermic-needle punctures. Rough handling of anaesthetic joints may be the source of trauma in these cases.

Frejka would include a fourth group in which, after muscle or joint inflammation, as in rheumatoid arthritis or rheumatic fever, there may be associated ossification of muscle and soft parts.

Blood-Chemistry Findings

The blood-chemistry studies on these patients are disappointing. It seems unusual that, with widespread osteoporosis and local osteogenic reaction occurring in such cases, some evidence of universal change is not detectable in the blood. Significant changes must be occurring, but not enough to alter the blood chemistry.

Frejka, in his cases of myositis ossificans progressiva, found no chemical changes or any mineral imbalance to account for the widespread sclerosis. He reports that many authors have investigated this problem, yet failed to find changes of significance. Stanger, in his report of two cases, revealed no calcium, phosphorus, or phosphatase changes.

The authors' studies on blood calcium, phosphorus, and phosphatase (Table I) showed nothing of significance. The calcium was well within the normal range, as were the

phosphorus and alkaline phosphatase. The entire blood picture failed to show any alteration. According to Best and Taylor, calcium-balance studies in some instances have revealed calcium retention with values of blood calcium and phosphorus that are normal.

Roentgenographic Findings

The roentgenographic findings in these patients are fairly obvious. Noble describes the shadows in myositis ossificans circumscripta traumatica as first being mottled and later homogeneous. Stripes and spots appear which correspond to muscle bundles and fascial planes. Stanger's films reveal a similar picture. The ossification is principally around the hips, as in our cases.

The authors' earlier roentgenograms were kidney, ureter, or bladder films, taken for genito-urinary calculi. The calcifications in the hips, as seen in these films, were incidental findings and were usually the first indication of musculoskeletal abnormality. The dense calcifications are about the hips, although several films show minor changes about the knees. The hip joints appear fairly normal, but they are somewhat obscured by the calcification, which is dense and trabeculated. It most commonly extends anteriorly from the anterior superior iliac spine over the hip joint and along the rectus femoris; either in addition to this course or as an alternative, it may descend medially from the iliopubic rami into the adductor muscle group. There may be a variable number of spurs, bands, or bridges of dense calcification from the trochanteric region of the femur to the acetabulum, ilium, or ischium. In Figures 1-A to 3-C, inclusive, which show progressive development of the myositis, diaphyseal calcification and knee involvement are illustrated.

Pathological Findings

The authors have obtained pathological specimens as well as seemingly normal tissue from the one patient operated upon. The anatomical and histological pathology was well described by Dejerine, Ceillier, and Dejerine, in 1919. The specimens which they presented were obtained from eleven patients, involving sixteen joints, and we have taken

FIG. 1-A

Case 5. July 19, 1946. Early evidence of process is visible over right trochanter.

FIG. 1-B

August 20, 1946. There is widespread evidence of early lesion. Shadows are soft but definite.

FIG. 1-C

December 28, 1946. Further advancement has occurred, medially and superiorly.

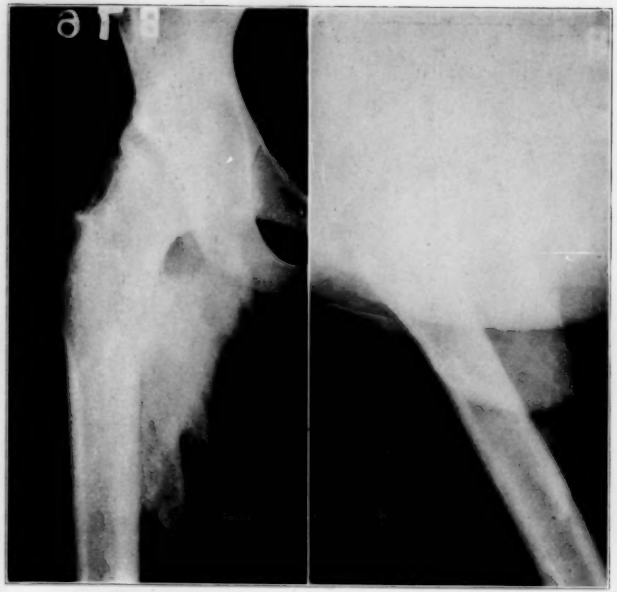

FIG. 1-D

FIG. 1-E

Figs. 1-D and 1-E: January 3, 1947. Anteroposterior and lateral roentgenograms show medial and anterior location of mass of new bone.

Fig. 1-F: May 26, 1947. Consolidation of lesion has taken place.

FIG. 1-F

the liberty of quoting extensively from their findings, because of the scarcity of reported material.

At the medial femoral condyle, Dejerine describes a compact bony nodule or prong, and, along the diaphysis, a fine lacework of spongy bone. The spongy bone approximates the calcification at the medial condyle and along the femoral shaft by contiguity rather than continuity. The hip joints present a bony scaffolding in three parts. Anteriorly, a band extends from the anterior inferior iliac spine to a line between the trochanters, in front of the joint capsule and beneath the iliopsoas. Posteriorly, the calcification extends from the ischium to the posterior border of the greater trochanter. Inferiorly, a more slender bridge arises from the iliopubic region and attaches at the lesser trochanter. The implantations about the femoral neck are compact bone, but the rest is spongy. The bone grows from each side and joins over the neck. The joints themselves are not involved, unless they are the site of purulent arthritis or osteo-arthritis. In the soft tissues far from the skeleton, new-bone growth appears in muscle. It begins as bony points or needles, disseminated under the fascial envelope of the muscle, in hyperplastic, dense connective tissue. Bony plates, formed in one patient, were found to be 18 centimeters long and 2 centimeters wide. These were irregular, jagged, and largely fenestrated. The tissue was rather compact under the anterior thigh muscles, but had no skeletal attachment. There was complete absence of infection or hemorrhage, nor was any new-bone formation seen in decubitus ulcers or scars.

Histologically, Dejerine's description is in accord with the authors' findings. Slender trabeculae, in cords or folds, limited the large medullary spaces. There was abundant vascularity in the marrow, which was rich in fat cells and connective tissue; and islets of hemorrhage were present. In the central portions between trabeculae, the marrow was made up of a fine, slightly vascular, reticular tissue, containing large fat cells, in the

FIG. 2-A

FIG. 2-B

FIG. 3-A

Figs. 2-A and 2-B: Case 2. June 3, 1946. Anteroposterior and oblique views of diaphyseal calcification.
Fig. 3-A: Case 4. November 15, 1946. Knee involvement is evident.

interstices of which were vividly colored myeloid cells. Toward the periphery, where the trabeculae join, the connective-tissue stroma was dense, vascular, hemorrhagic, and continuous with the fibrous wall, similar to periosteum. Lining this layer, next to the trabeculae, were cells like cylindrical epithelium, similar to osteoblasts. The trabeculae showed a regular or irregular series of bone cells in uneven thickness of bony lamellae. These were avascular, but had Haversian canals, around which bone cells were disposed in concentric lamellae. In one case, plaques of cartilage were also present. The cartilage cells were not grouped in orderly patterns and were varied in shape, some being globular and others elongated. In some places these cells were immersed in a basophilic substance which tended toward a zone of acidophilic staining. Other cells, however, stained poorly, were scarce, and were surrounded by a substance only slightly basophilic. Outside of this was the osteoblastic layer. Near centers of ossification, true intramuscular and perimuscular sclerosis occurred. In one case, the cross striations of muscle were gone and there was a proliferation of the nuclei of the sarcolemma. The fibers were atrophic and segmented, as in any lesion of the cord or roots. The muscle fasicles were separated and appeared drowned in a connective-tissue oedema.

The gross pathological findings in the authors' case were described by Dr. Fred Hark at the time of surgery. Both the right and left hips were operated upon, because the patient was unable to sit in a wheel chair. In the right hip the calcification was found to involve the rectus femoris, from its origin to the junction of the proximal and distal half of the muscle. The joint capsule was calcified, and the vastus lateralis also had some calcium deposits. A lip of calcification extended from the anterior inferior iliac spine

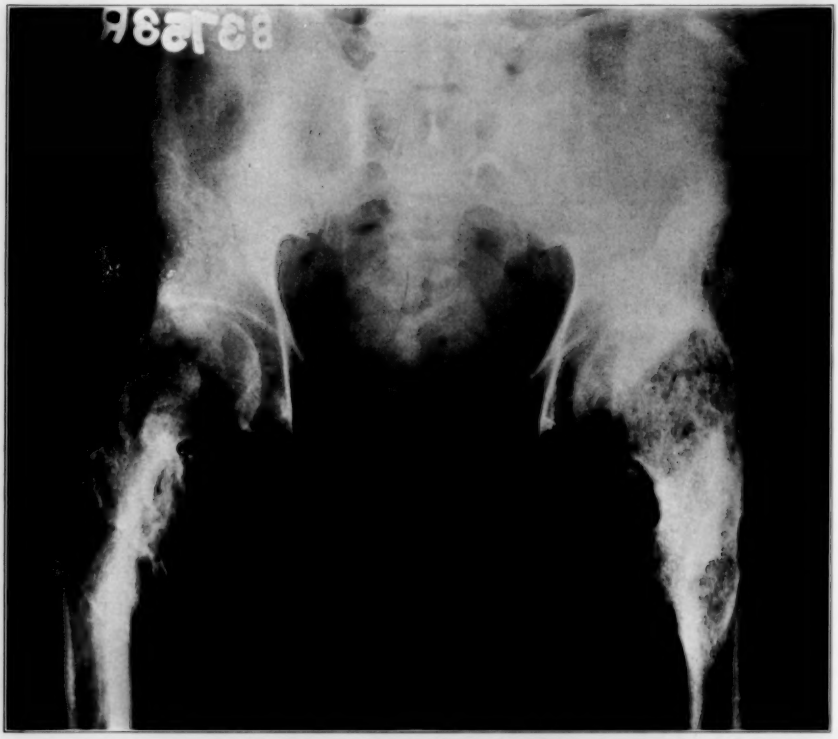

FIG. 3-B

November 15, 1946. Preoperative film of lesions of both hips, limiting hip motion.

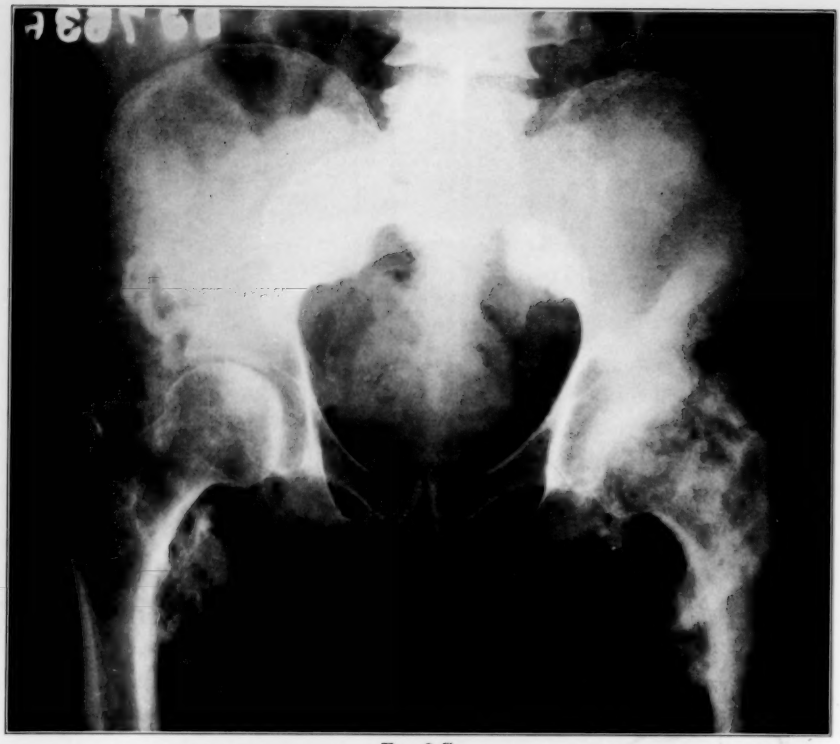

FIG. 3-C

February 5, 1947. Postoperative film after surgical procedures on both hips.

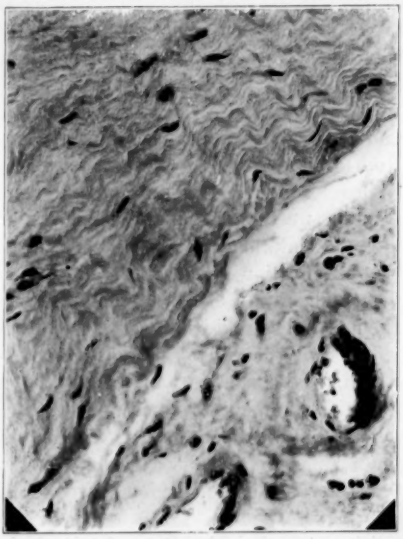

FIG. 3-D

FIG. 3-E

Fig. 3-D: High-power view of fibrosis within the degenerated muscle tissue.

Fig. 3-E: Dark-staining cartilaginous tissue with border of osteoblasts laying down new bone. At the top is osteoid tissue.

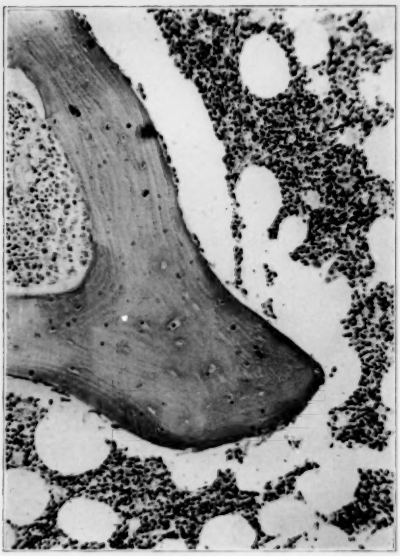

FIG. 3-F

FIG. 3-G

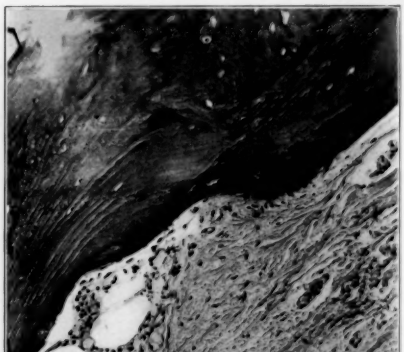

FIG. 3-H

Fig. 3-F: Low-power photomicrograph of bone trabeculae with surrounding marrow cells, as in adult bone.

Fig. 3-G: High-power view of adult bone and marrow cells.

Fig. 3-H: Lower portion shows atrophic muscle and fibrosis, with portion of adult bone at top.

downward and medially, blocking the front of the hip joint. The femoral head and acetabulum were normal. On the left hip, the rectus femoris was involved from its origin to the mid-thigh. Calcification was lobulated and covered by a connective-tissue sheet, from which adjoining tissues were easily stripped away. A few fibrous bands came from between the lobulations, particularly along the lateral aspect. Upon chiseling into this calcification, it was observed that there was a suggestion of a thin cortex and that the internal composition of the calcification was a fairly dense cancellous type of bone, which, for the most part, appeared white and lacked any amount of vascularity. In the lower portion, however, at least two vessels were severed, and one in the extreme upper pole of the wound caused a moderate amount of hemorrhage. The cancellous bone involved the anterior portion of the capsules of the hips. The head of the femur was soft and compressible upon direct pressure with the finger.

Histologically, two separate reports from different pathologists were obtained of the same slides and were practically identical. There was marked fibrosis and degeneration of the muscle with atrophy. The new-bone formation appeared entirely normal and con-

TABLE I

ANALYSIS OF CASES

Case No.	Levels of Lesion	Spasm	Genito-Urinary Calculi	Period Prone	Calcium (9 to 12 mg./100 c.c.)	Phosphorus (2.5 to 4.5 mg./100 c.c.)	Alkaline Phosphatase* (0.5 to 5.0 Bodansky Units)
1	Second lumbar	++	No	1 year	9.7	3.7	3.8
2	Fourth, fifth, and sixth thoracic	+	No		11.6	3.6	4.0
3	Third and fourth thoracic	+++	No	2 months	11.5	3.6	17.1 and 8.5
4	First lumbar	0	No		11.0	3.6	6.9
5	Sixth thoracic	+++	Yes	2 years	10.8	4.5	5.1
6	Fifth thoracic	++	No	3 months	10.8	3.5	2.8
7	First lumbar	0	Yes	Frequently since injury in 1935	10.9	3.5	6.3
8	Twelfth thoracic	+	Yes	2 months	11.2	4.4	10.2
9	Ninth thoracic	++	No	2 months	10.9	3.7	3.9
10	First lumbar	+	No	6 months	10.4	3.4	5.9

* Alkaline-phosphatase values, as determined in our laboratory, are felt to be of little significance until elevated above 10 units. Case 3 shows a high value which was rechecked and found to be nearly normal. This patient was physically inactive, and showed a marked increase in his osteoporosis and progressive stiffness of the joints of the lower extremities. Case 8 shows a high value, possibly because there was some evidence of extension of the original myositis ossificans.

tained normal marrow blood-forming cells. The bone trabeculae were of the adult type. One area showed the deposition of calcium salts within and around young cartilage cells and osteoid tissue. Except for this one area, no active osteoblastic proliferation was seen. Throughout the slides there were dense collagenous deposits with few cells, and in the areolar tissue and fat were numerous blood vessels (Figs. 3-D to 3-H, inclusive).

Theories of Formation

Many theories exist for the development of myositis ossificans. Each can be applied to a particular case and would adequately explain why new bone is formed, but no one theory explains why osteogenesis occurs instead of fibrosis. The particular elements present which make the situation favorable for bone formation are discussed by various writers.

Dejerine and her associates attach considerable importance to the subcutaneous and deep oedema of the tissues, which modifies or alters in some way the resistance of the connective tissue, and to the functional irritability of the nerve elements of the intermediate lateral sympathetic column of the spinal cord, immediately adjacent to the traumatic lesion. They feel that detachment of the periosteum could explain ossification around the epiphyseal and diaphyseal portions of the bone, but that it does not explain the intramuscular ossification. They believe that a metaplasia occurs.

This group of workers further contend that all primitive connective tissue is capable

of forming fibrous tissue, tendon, muscle, cartilage, or bone, since all have a common origin from mesoblastic tissue. Perhaps by cord trophism, under the indirect influence of oedema and of functional irritation from the intermediate lateral sympathetic column, and under the direct influence of necessary handling of patients, which produces traction on connective tissue, ligaments, muscles, and tendons, metaplastic phenomena are produced, causing para-osteo-arthropathies in these paraplegic patients.

Stanger recently suggested two possible causes for osteogenesis in transverse cord lesions. The first is "impaired urinary excretion of nitrogenous bodies, causing a mobilization of calcium from the bones of the paralytic limbs". Second, a Charcot-like reaction occurs around a denervated joint, subjected to passive stretching.

In transverse cord lesions, Geldmacher's theory from the study of his cases was analogous to that of Leriche. Geldmacher believed that the tissue loses its character by trophic influences and assumes the character of embryonic tissue. Calcium salts are mobilized from the atrophic bone which accompanies the paralysis, making the situation favorable for bone formation. Frejka gives Leriche's theory of the conditions necessary for bone formation: (1) embryonic connective tissue, stimulated by hemorrhage, rheumatic or purulent inflammation, trophic changes from cord lesions, et cetera; and (2) local increase in lime salts in lymph, produced by absorption of adjacent bone. He thinks that the local ossification differs from the progressive form in that a general predisposing dystrophy or diathesis is lacking, but that all types of myositis ossificans should be considered as the same malady.

NOTE: This paper is published with the permission of the Chief Medical Director, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or the conclusions drawn by the authors.

The patients studied were cared for on the Paraplegic Service, which is under the supervision of the Department of Nervous and Mental Diseases of Northwestern University Medical School, through the auspices of the Deans' Committee of the Veterans Administration Hospital, Hines, Illinois.

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KÜNTSCHER'S MEDULLARY NAILING

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At the sixty-fourth meeting of the *Deutsche Gesellschaft für Chirurgie*, held at Easter time, 1940, Küntscher presented his new method for the treatment of fractures of the shafts of the long bones. His method, which is employed after exact reduction of the fragments, consists in the insertion of the so-called "medullary nail", a long stainless-steel pin, through a small incision at a point away from the fracture site. This medullary nail unites the fragments so firmly that, as a rule, the fractured limb can be lifted at once and can be moved actively without additional external support, like the nailed fracture of the neck of the femur. After bony union, the medullary nail can easily be removed by a simple operation.

Closed medullary nailing has two great advantages over former types of osteosynthesis,—namely (1) almost complete avoidance of infection; and (2) complete stability, so that, as a rule, no other supports have to be used.

In fractures of the femur, the fragments can slide along the nail and be pressed together. The medullary nail eliminates all detrimental factors of traction and sheering, and only the favorable factor of pressure exists. The callus formation is thereby enhanced, while it is often hindered by the use of plates, as the fragments are held apart (Figs. 8-A and 8-B). Furthermore, with closed medullary nailing, the hematoma and fracture detritus so important for the regeneration of bone are retained, and the periosteum and adjoining tissues are not further traumatized. The three main rules of fracture treatment—reduction, fixation, and exercise—are accomplished in an ideal manner.

Therefore, in properly selected fractures of the shaft of the femur, closed medullary nailing is far superior to all known forms of treatment. This method has also proved worth while in the treatment of localized osteitis fibrosa cystica of the femur and the humerus (Figs. 5-A, 5-B, and 5-C).

Küntscher recommended his method for fractures of all long bones. The authors have used medullary nailing since 1940 in about 700 cases. Except in fractures of the femur, we now use it only occasionally in closed transverse fractures of the humerus; we no longer use it for fractures of the tibia or of the forearm.

Some time ago, feeling that our results were unsatisfactory in fractures other than those in the femur, we reviewed all of our cases. The review indicated that, in bones other than the femur, the results were better by conservative methods than with nailing. In many cases, fixation of the tibia by the nail is not mechanically firm enough to eliminate the need for external fixation by plaster. As a result of the curved path of the nail in the tibia, the metal must of necessity be bent and may hinder approximation of the fragments by diastasis of the bone ends, leading to delayed union or even to non-union. Because of these complications and because healing may be greatly delayed through minor technical errors, the authors have completely abandoned the use of the intramedullary nail in the tibia. These findings were emphasized even more strongly in ununited fractures and in compound fractures of the tibia.

The use of the nail has also been discontinued in forearm fractures, for the same reasons. In fracture of a single bone of the forearm, coaptation can be maintained by simpler means. If intramedullary fixation is used in fractures of both bones, it is necessary to fix both bones. In the radius, as in the tibia, the bent nail is undesirable.

The theoretical objections raised against medullary nailing have been refuted by practical experience. In adults, the amount of destruction of the bone marrow by the

medullary nail is of little significance. The medullary nail is a large foreign body. It will not, however, cause significant reaction if a completely inert stainless steel is used; lytic effects are noted only with stainless steel which is not completely inert. The medullary nail hinders callus formation, as does every foreign body, and is not, as Küntscher thought, conducive to callus formation. An increased formation of callus appears only if the medullary nail does not fix the fragments sufficiently or if an oxidizing metal is used. By the mechanical or electrochemical activity an irritation callus arises, and for a long time the limb cannot be trusted to bear weight.

The insertion of the medullary nail does not cause a clinically evident fat embolism, because by its construction the nail permits the marrow to flow through it, and, therefore, does not act like a piston. When a solid steel rod is used instead, fat embolism may occur. Infections are infrequent with medullary nailing; however, if an infection should arise, the whole marrow cavity along the nail might become infected. We have in our own cases not seen any serious progressive infection as a result of closed medullary nailing. Krenslehner reported acute and fatal osteomyelitis in an adolescent. Therefore, we do not nail fractures in bones in which the epiphyses have not yet closed.

Although the danger of medullary nailing seems to be small, the authors, while examining about 700 cases in different hospitals, have seen a great many complications, due to faulty indications, improper technique, improper instruments, or faulty material. The most serious, and even fatal, incidents occurred because the operation was performed while the patient was in shock.

Exact indications are necessary. The most suitable fractures are transverse and short oblique fractures at the middle third of the femur; they should be at least seven centimeters from the tip of the trochanter or from the knee joint. The patient must be in good general condition. The skin must be intact and show no inflammation or burns. Other foci, a possible cause of metastatic infection of the fracture, should be ruled out. Absolutely no shock should be present. This danger is especially great if the nail used is too wide, since force is necessary to drive it in and death may occur.

The proper instruments must be available, including nails of the proper length and width and sufficient instruments for a bone operation. A special reduction apparatus is necessary for closed nailing. The authors use either their screw-traction apparatus (Fig. 1) or Wittmoser's reduction apparatus (Fig. 2). Two portable x-ray machines are needed to afford biplane roentgenographic control without changing the position of the machine.

The operation is performed with repeated roentgenographic checks, so that care must be taken to prevent x-ray burns. In order to protect the patient, the x-ray tubes must be kept at least thirty centimeters from the skin. The fluoroscope operator should be allowed to work only when protected with lead apron and lead gloves. A reduction apparatus must be used, which reduces the fragments and maintains position mechanically. Inattention to these details may result in severe x-ray burns, as happened so often to older roentgenologists or orthopaedic surgeons.

Closed Medullary Nailing of the Femur

Closed fractures are best nailed within the first hours of injury. If shock is present, it is well to wait from eight to ten days, until the acute reaction has subsided. In the meantime, skeletal traction is applied.

After the width and the length of the bone have been determined by means of good roentgenograms, and after proper medullary nails have been selected, spinal anaesthesia is given. The patient is placed on a reduction apparatus (Figs. 1 and 2). With fractures of the lower third of the femur the knee should not be extended, but semiflexed (Fig. 2). One x-ray machine is placed at the ventral aspect and a second one at the medial side of the thigh. By means of longitudinal traction, the shortening will be overcome; and by means of canvas slings or wooden rings, attached to rotating bars, the lateral displacement is cor-

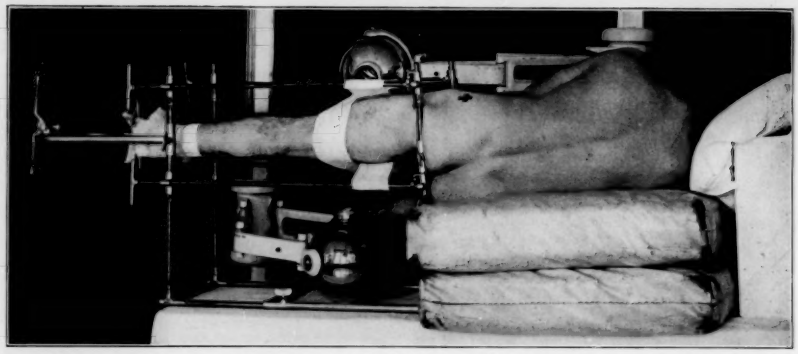


FIG. 1

The femur is fixed for medullary nailing in the Böhler screw-traction apparatus. The patient lies on the well side, bent slightly forward so that the greater trochanter is better exposed. The uninvolved extremity is acutely flexed at the hip. The point of insertion of the medullary nail is marked with a cross. The fragments are reduced and fixed firmly in correct position by means of rotating double bars and canvas slings. Two x-ray tubes are placed in position for fluoroscopy and roentgenography. (Reproduced, by permission of The Williams and Wilkins Company, from *Medullary Nailing of Küntscher*, by Lorenz Böhler.)

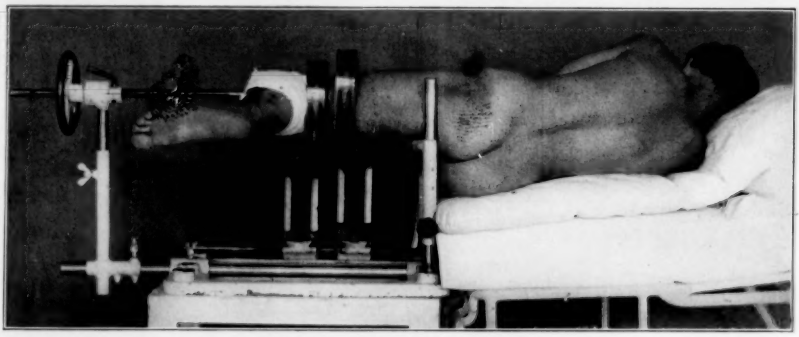


FIG. 2

Fracture of the femur, with patient placed in Wittmoser's reduction apparatus. In fractures close to the knee joint, the knee is flexed to a right angle.

rected. If fluoroscopic control shows good reduction from each side, roentgenograms are taken. If they show good alignment of the fragments, the area of the hip is prepared in a sterile manner.

An incision of about two to three centimeters in length is made, five centimeters above the tip of the trochanter. An awl is inserted, to the medial side of the greater trochanter, into the marrow cavity. The nail guide is then inserted, by means of a handle, through this hole, its course being checked by fluoroscope. As the guide advances toward the knee joint, additional roentgenograms are taken. When they reveal a satisfactory position, the medullary nail is driven over the nail guide with a hammer, again under fluoroscopic control. As the medullary nail approaches the skin, the nail guide is withdrawn and the nail is hammered farther in with a nail-driver, until it extends only two centimeters from the tip of the trochanter and one centimeter from the knee joint. The wound is then closed and again roentgenograms are taken. Should diastasis exist at the fracture site, it is overcome by a strong thrust with the flat of the hand against the knee joint.

Reduction may be very difficult and should never be tried without a reduction apparatus. The insertion of the nail guide may also be troublesome, but usually no difficulties arise in driving in a nail of the proper width.

After the operation, the lower extremity is placed on a Braun frame, and the toes and ankle joint are moved actively from the first day. The hip and knee joint should not be

FIG. 3-A

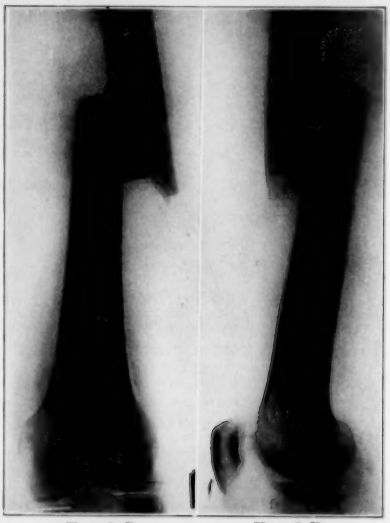


FIG. 3-B

FIG. 3-C

FIG. 3-D

Figs. 3-A and 3-B: September 16, 1947. Compound fracture of the right femur between the middle and lower thirds.

Figs. 3-C and 3-D: September 16, 1947. Closed transverse fracture of the shaft of the left femur. Skeletal traction was applied through the tuberosity of the tibia.

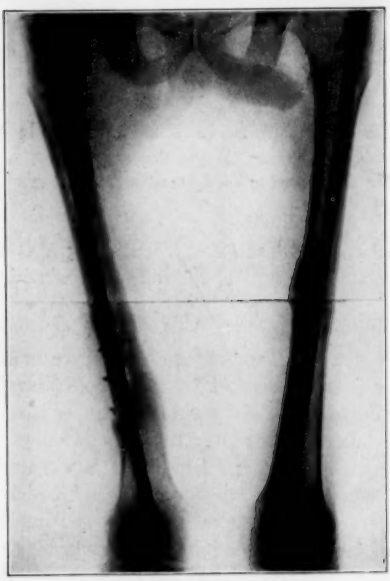


FIG. 3-E

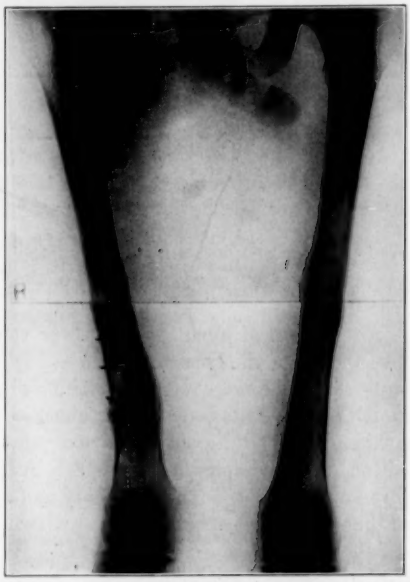


FIG. 3-F

Fig. 3-E: July 20, 1948. On the right side the wound was excised immediately, a medullary nail was inserted, and three encircling wires were applied. Healing occurred without wound complications. Closed medullary nailing was accomplished on the left side, sixteen days after the accident. Solid bony union and good position resulted on both sides.

Fig. 3-F: July 29, 1948. After removal of the nails, ten months after the accident.

moved until eight days after operation. If the nail is in good position and no other injuries exist, the patient may start weight-bearing after eight to ten days, and he may leave the hospital after two or three weeks.

Closed Medullary Nailing in Localized Osteitis Fibrosa Cystica

The cyst is located usually in the upper third of the femur or the humerus, seldom in other bones. It is a typical disease of pressure. By pressure the bone is resorbed until finally only a paper-thin cortex remains, because there is no simultaneous periosteal apposition (Fig. 5-A). An insignificant force finally causes a pathological fracture. Thus the wall of the cyst is opened and the pressure is released. New-bone apposition occurs and, as a rule, the fragments unite. Sometimes the cyst heals completely, but generally a new one is formed, because the wall of the cyst is closed by callus formation and new pressure arises.

The ailment can be healed by opening and curettage or, better, by filling the defect with bone grafts or bone chips. In the case illustrated here (Figs. 5-A, 5-B, and 5-C) the authors inserted a medullary nail. By this procedure alone, without curettage or bone-grafting, the condition healed completely.

A woman, aged twenty-eight, of good general condition, fractured the right humerus in May 1946. Prior to this she had occasionally had pain in the right shoulder. The roentgenograms showed a cyst in the right humerus, with a fissure. The fracture healed

FIG. 3-G FIG. 3-H

February 12, 1948. Function five months after the accident. Patient had started walking four weeks after the accident, and six weeks later could bend both knees to 90 degrees.

FIG. 4-A FIG. 4-B

Figs. 4-A and 4-B: July 7, 1948. A policeman, thirty-four years old, sustained a compound, comminuted fracture of the left femur in a street accident, with wounds on the anterior and posterior aspects of the thigh. Marked posterior displacement of the distal fragment can be seen.

FIG. 4-C FIG. 4-D

Figs. 4-C and 4-D: August 9, 1948. Five weeks after the accident. After thorough excision of the wound, open medullary nailing was performed and four encircling wires were applied. Healing took place without wound complications. Weight-bearing not yet allowed.

FIG. 5-A FIG. 5-B FIG. 5-C

Fig. 5-A: January 14, 1947. A librarian, twenty-eight years old, had a solitary cyst in the head of the right humerus, about 3.5 by 5 centimeters in size. The cortex was only 0.5 millimeter thick laterally.

Fig. 5-B: July 14, 1947. Six months after medullary nailing, the area of the cyst had nearly filled in with newly formed bone tissue. The medullary nail remained in place.

Fig. 5-C: June 23, 1948. Seventeen months after medullary nailing and immediately after removal of the nail, the former cyst had completely filled with new-bone tissue. No discomfort remained.

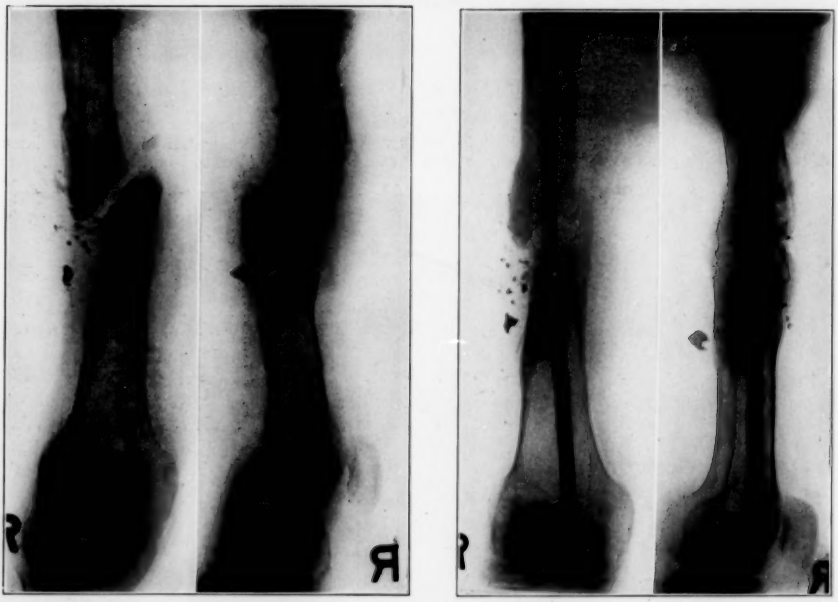
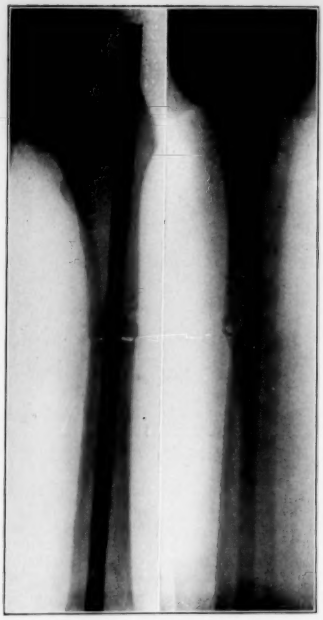


FIG. 6-A FIG. 6-B FIG. 6-C FIG. 6-D

Figs. 6-A and 6-B: January 10, 1946. Pseudarthrosis of the right femur in a student, twenty-three years old, due to gunshot fracture, three years before. Numerous shell fragments remained. Sclerosis was present at the fracture site.

Figs. 6-C and 6-D: June 1, 1947. Seventeen months after open medullary nailing, the nail, which was short, had become loose. As a result there was no bony union and the nail had broken. After correction of angulation, the medullary nail was removed through a small incision in the trochanteric area and was replaced by a longer one. The knee joint was later mobilized by open operation.



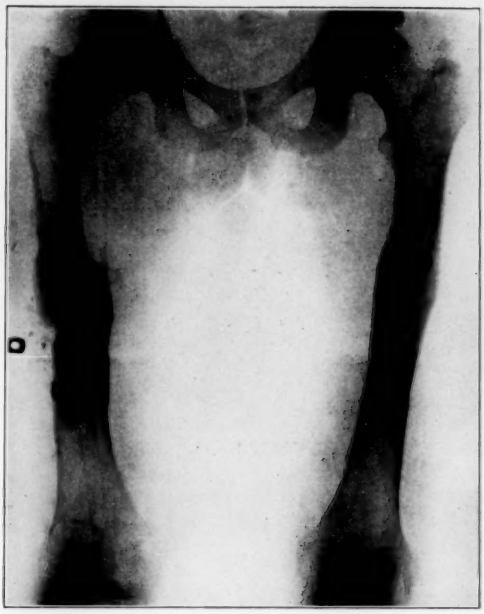


FIG. 6-E FIG. 6-F FIG. 6-G

Figs. 6-E and 6-F: July 17, 1946. The left femur was shortened eight centimeters, and a medullary nail and a wire loop were inserted.

Fig. 6-G: March 9, 1948. After removal of the medullary nails, both femora had healed in good position and were the same length.

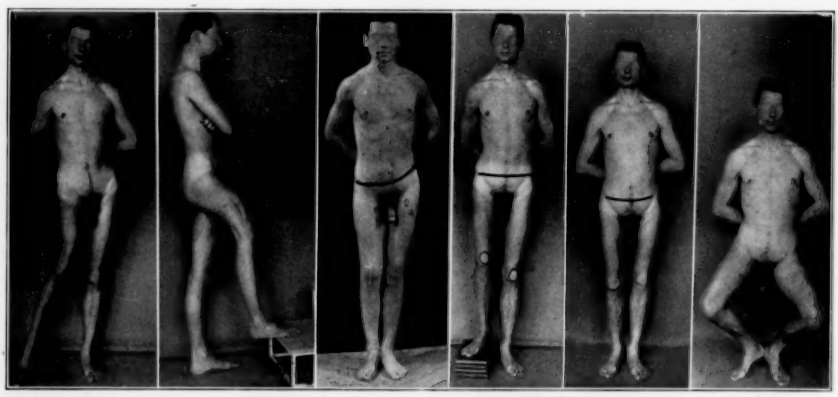


FIG. 6-H FIG. 6-I FIG. 6-J FIG. 6-K FIG. 6-L FIG. 6-M

Figs. 6-H and 6-I: January 19, 1946. Photographs before treatment show abnormal mobility and shortening of nine centimeters. Knee-joint range from 170 to 160 degrees.

Figs. 6-J and 6-K: June 16, 1946. After medullary nailing of the pseudarthrosis, shortening of the right lower extremity was still present.

Fig. 6-L: March 9, 1948. After shortening of the left femur, both extremities were the same length.

Fig. 6-M: March 9, 1948. After open mobilization of the knee joint, knee flexion was possible to 90 degrees.

without incident. In July 1946, the patient came to our Hospital. In January 1947, a medullary nail was driven into the cyst and the arm was immobilized for ten days. Soon afterward the shoulder joint was free and the pain had disappeared. The cyst was almost completely filled with new-bone tissue; remains of the

FIG. 7-A FIG. 7-B FIG. 7-C FIG. 7-D FIG. 7-E FIG. 7-F

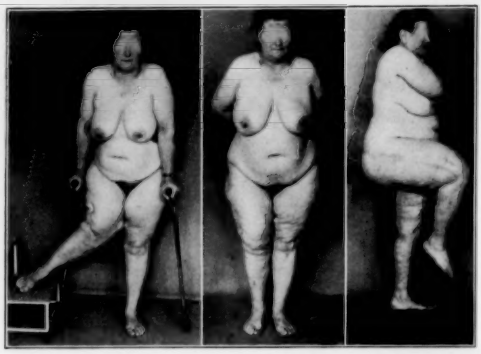


FIG. 7-G FIG. 7-H FIG. 7-I

Figs. 7-A and 7-B: January 10, 1946. Pseudarthrosis of the right femur of two years' duration, following infected compound fracture after a motorcycle accident in a landlady, fifty-one years old. Height 165 centimeters (65 inches); weight 90 kilograms (198 pounds). Shortening of five centimeters and marked atrophy of the bones were present.

Figs. 7-C and 7-D: January 26, 1946. The shortening was corrected after fourteen days of skeletal traction, and open medullary nailing was performed. Ideal position seen from both sides. The fragments were held by a wire loop against rotation, and one rubber drain was left. The patient walked without external fixation three weeks after operation.

Figs. 7-E and 7-F: March 17, 1948. After removal of the medullary nail, bony union was present with the fragments in ideal position. The patient fractured the patella in a fall.

Fig. 7-G: January 11, 1946. Photograph before treatment shows abnormal mobility at the fracture site.

Figs. 7-H and 7-I: March 17, 1948. Two years after operation patient had good use of extremity and was able to walk without a cane. Range of knee motion from 160 to 90 degrees.

cyst are still to be seen (Fig. 5-B). One and one-half years after the operation the nail was withdrawn (Fig. 5-C). The apposition of bone inside the cyst had taken place without incident, because the pressure was released, as the nail drained the cyst constantly.

Unlike curettage and bone-grafting of the area containing the cyst, medullary nailing is a simple procedure and not dangerous. No further fixation is necessary, because the medullary nail gives sufficient support. The authors have operated upon three solitary cysts of the femur in the manner described here, with the same good results.

Medullary nailing can also be used in spontaneous fractures occurring at the site of metastases of malignant tumors, which are found mostly in the upper third of the femur. The patients can walk on the extremity with the nail, although the fracture fragments will not reunite.

Open Medullary Nailing of the Femur in Compound Fractures (Figs. 3-A through 4-D)

With open medullary nailing the fragments must be freed, as in any other form of osteosynthesis. The great advantage of closed medullary nailing, the small danger of in-

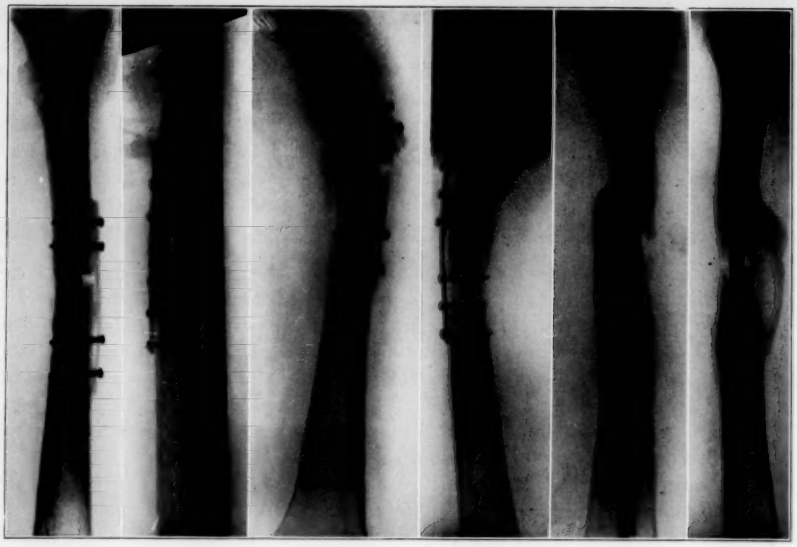


FIG. 8-A FIG. 8-B FIG. 8-C FIG. 8-D FIG. 8-E FIG. 8-F

A postman, thirty-two years old, fractured his left femur a year and a half prior to admission. Wire traction was applied for seven months with ten to twenty kilograms of weight (twenty-two to forty-four pounds). A pseudarthrosis resulted and osteosynthesis was done with bone graft and plate. (Observation of Dr. Neubauer, Graben Hospital, Graz.)

Figs. 8-A and 8-B: May 3, 1946. Very good position resulted after operation with bone graft and plate for pseudarthrosis of left femur. Diastasis was present at the fracture site.

Figs. 8-C and 8-D: December 7, 1946. In spite of three months' fixation in a hip spica, no bony union resulted. The bone graft broke and angulation of fragments occurred. Varus and anterior angulation are shown, each of 30 degrees.

Figs. 8-E and 8-F: Bone graft and plate were removed and one month later medullary nailing was performed. Thirteen months later (on August 5, 1948), the patient could walk several hours without a cane and was doing full duty as postman. The medullary nail was still in place and he had no complaints.

fection, does not apply; but the other advantages—namely, stable union of the fragments and free mobility of the limb—still exist.

The indications for open medullary nailing must be given exactly. The authors never use this form of treatment in infected and draining fractures. They use it in all recent compound fractures of the shaft of the femur without joint involvement, and in those patients whose general condition permits.

Open medullary nailing is much easier to perform than closed. After exact débridement of the wound, with the patient under local anaesthesia, the nail guide is inserted into the central fragment from the fracture site and is advanced through the tip of the trochanter to the skin. A skin incision, two or three centimeters in length, is made at the point where the guide appears under the skin; and a short medullary nail is driven from above, over the nail guide, one centimeter into the trochanter. The nail guide is pulled out and a new one is inserted from above, through the medullary nail, into the central fragment, until it appears at the fracture site. Then both fragments are approximated and held by means of bone forceps, and the nail guide is inserted into the distal fragment until it reaches the region of the knee joint. If the position of the fragments and of the nail guide is satisfactory, as ascertained by two check roentgenograms, a medullary nail of the proper length and width is driven in and the fragments are impacted by thrusts on the knee with the flat of the hand. Rotation is controlled by means of a longitudinal wire loop (Figs. 6-G and 7-C to 7-F). In oblique and spiral fractures, an encircling wire is applied. After insertion of a rubber drain, the skin is closed.

The leg is placed on a Braun frame, as is done after closed medullary nailing. The drain is removed after twenty-four hours. The toes and ankle joint are moved, beginning on the first day. Motion of the knee joint is started three weeks later. If the wound heals without incident, the patient may get up during the fourth week.

To date the authors have nailed about thirty fresh open fractures of the femur. In only one case did a slight infection develop. Five months later a small sequestra was removed and the existing fistula was closed.

Open Medullary Nailing in Cases of Malunion or Non-Union of the Femur (Figs. 6-A to 8-F)

When a fracture of the femur has united with shortening of more than three centimeters and with angulation or rotation of more than 15 degrees, the patient limps. Later, osteo-arthritic disturbances develop in the hip and the knee joint, and occasionally even in the ankle joint of the injured limb; and, in marked shortening, also in the sound limb and in the spine. Non-union of the shaft of the femur cripples the patient severely and should be corrected. Especially in these cases with malunion or non-union, medullary nailing represents great advance, because no external support is necessary and the atrophic muscles and joints with limited motion do not need to be immobilized further.

Contra-indications for the operation are found: (1) in an unfavorable general condition; (2) in osteotomies in patients over fifty; (3) in non-unions in patients over sixty; (4) in patients under sixteen, because of the danger of acute osteomyelitis; (5) in infections of the bone and the skin; and (6) with enlarged ossifications of the marrow cavity due to old callus formation. Fistulae should have been closed for six months to one year. All scars, especially when adherent to the bone, should have been excised previously. Medullary nailing should be performed only after the new scar has become firm and is easily movable on the base; usually this takes about two or three months.

If shortening of more than three centimeters is present, it is very difficult to reduce this during operation, because the muscles are contracted. If an attempt is made to equalize greater shortenings by medullary nailing, severe vessel and nerve disturbances may occur as the result of the sudden tension, and wound infection may arise in the torn tissue. Therefore, the shortening must be corrected prior to medullary nailing. If the callus is not yet solid, the osteoclast may be used. If the callus is solid, the bone is cut with the chisel or the electric saw,—if possible, in the old fracture site. With non-union, the solid connections of the fragments are loosened by bending them over a wedge or with the osteoclast. If the inflammation of infected fractures does not flare up, it probably will not recur after the medullary nailing. Skeletal traction with adequate weight is next applied. After length has been restored, the medullary nailing can be performed. In the case of a closed osteoclasis, this is generally after one week; in the case of an osteotomy, about three to four weeks should pass.

The medullary nailing is performed with the patient in the lateral position, a sterile tourniquet being used. After the fragments have been freed, a longitudinal mark, five to six centimeters long and one to two millimeters deep, is cut into the bone with a small gouge, so that the amount of rotation can be determined. With angulation a corresponding wedge must be sawed, so that the fragments will touch each other exactly. The closed marrow cavity is opened with the awl or the gouge. In more recent cases, the authors have always bridged the fracture site with a piece of removed callus, a bone graft, or chips. The operation continues as for an open fracture, precautions against shock being observed.

Shortening of the Uninvolved Extremity by Medullary Nailing

If an unusual amount of shortening is present and the bone is not suitable for lengthening, only the angulation of the injured limb is corrected. After the patient has completely recovered from the first operation, the sound femur is shortened to equal the length

of the broken femur. This should not exceed eight or nine centimeters, because of the difficulty in accommodation of the muscles (Figs. 6-A to 6-M).

After application of a sterile tourniquet, the sound femur is exposed above the middle third. A longitudinal marker, adequate to indicate rotation of the fragments, is chiseled out. Then the bone is sawed through transversely at the edge of the upper and middle thirds, a Gigli saw being used. The distal fragment is elevated and the correct length of bone is removed. Both saw cuts are thus in the narrow portion of the marrow cavity. To avoid rotation, step-cutting may be used, but transverse cutting is easier. Of late the authors have cut from the resected bone one or two strong grafts to bridge the site of the osteotomy. The operation then is continued as for an open fracture.

SUMMARY

At present, medullary nailing by the method of Küntscher is the best treatment for transverse closed fractures, for open fractures, and for most of the osteotomies and nonunions of the shaft of the femur, if suitable equipment is available. The union of the fragments is so firm that the patient can walk without additional fixation after the wound has healed,—that is, in two or three weeks. Thus muscle atrophy and stiffness can be almost entirely prevented. With closed medullary nailing, the danger of infection is slight, because only a small incision is made apart from the fracture site. With open medullary nailing, the danger of infection is reduced by exact immobilization.

The authors also use medullary nailing for closed transverse fractures in the middle third of the shaft of the humerus. They no longer employ this method for fractures of the tibia or the forearm, as conservative methods have proved to be better.

Medullary nailing is a technically difficult procedure and should, therefore, be done only in specially equipped hospitals.

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SPONTANEOUS SACRO-ILIAC OBLITERATION IN PATIENTS WITH TUBERCULOSIS

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It is now recognized that the poor prognosis previously ascribed to tuberculosis of the sacro-iliac joint was the result of the associated widespread dissemination of the tubercle bacillus, rather than to the local disease process. Little has been written regarding the natural history and termination of the disease process in the joint under modern conservative management. The consensus in this country is that, in order to obtain bony ankylosis of this joint, operative intervention is necessary. The authors have recently observed, as an incidental finding in several patients coming to the Clinic for treatment of tuberculosis of the spine or hip joint, that one of the sacro-iliac joints has been obliterated by bony trabeculations. If these lesions represent the end result in patients with sacro-iliac tuberculosis who have not been operated upon, they lead one to question the advisability of bone-graft procedures for osseous fixation of the joint.

FIG. 1

A. K., January 16, 1945. Complete obliteration of the left sacro-iliac joint, represented by sclerotic changes. (Right joint entirely normal on detail films.)

EXPERIMENTAL DATA

Because the first sacro-iliac lesions recognized (Fig. 1) were incidental findings in patients with tuberculosis elsewhere in the body, it was felt that the best means of locating such lesions would be by reviewing all of the roentgenograms of the spine of patients at the Michigan State Sanatorium (for tuberculosis). Accordingly, the films of approximately 330 patients, representing the roentgenographic examinations of the back in approximately 6,600 patients admitted from 1930 to 1947, were reviewed. Twenty-two patients were

found with destructive and obliterative lesions, either alone or in combination, of *one* sacro-iliac joint. To this group was added one patient who has been under observation at the University Hospital, but who was not cared for at the state institution.

Fifteen of the patients were males and eight were females. Their ages ranged from eight to sixty-two years, with twenty falling in the three decades from eleven to forty. The average age was twenty-eight years. Nineteen of the patients were white, one was a Mexican, one a negro, and two were Indian.

These patients were under observation for periods varying from one month to thirteen years. The average duration of observation for patients, either at the Sanatorium or in the Out-Patient Department of the University Hospital, was approximately thirty-eight months.

FINDINGS

Seventeen (74 per cent.) eventually had partial or complete obliteration of one sacro-iliac joint by bony ankylosis. In fifteen of these patients, bacteriological proof of tuberculosis elsewhere in the body was obtained.

Nine (39 per cent.) of the seventeen patients, in their initial roentgenograms, presented partial or complete osseous ankylosis of a sacro-iliac joint (Fig. 2). One had a draining tuberculous gluteal abscess on the side of the sacro-iliac involvement, which was interpreted by the examining physician as having arisen from concomitant lumbosacral Pott's disease. This patient and two others had roentgenographic evidence of quiescent destructive lesions at other locations in the joint, associated with the osseous ankylosis. Six patients showed evidence of obliteration without associated destruction.

In the remaining eight patients with eventual fusion of one sacro-iliac joint, progressive destructive changes, with eventual healing while the patient was under hospital observation, were demonstrated on serial roentgenograms. Of this group, three underwent operative fusion, and in two the tubercle bacillus was proved pathologically to be the etiological agent. The third patient was an Indian who had a healed primary pulmonary tuberculous lesion, a strongly positive tuberculin reaction (1 to 10,000), and a history of recent tuberculous contact. The pathological material obtained at operation failed to reveal any inflammatory tissue. However, the roentgenographic changes were typical of a destructive inflammatory disease of the joint.

Of these eight patients, one presented a picture of multiple soft-tissue abscesses and roentgenographic evidence compatible with

FIG. 2

FIG. 3

Fig. 2: L. L., December 29, 1945. Right joint completely obliterated by osseous trabeculations. Left sacro-iliac joint apparently healed by "fibrous ankylosis".

Fig. 3: W. C., March 15, 1937. Complete bony ankylosis through mid-portion of the joint, with apparent quiescent destructive lesions above and below fused area.

FIG. 4-A

FIG. 4-B

FIG. 4-A: A. H., May 4, 1937. Destruction has occurred superiorly and inferiorly, with a sequestrum in the inferior cavity. Apparent early fusion is seen through mid-portion.

FIG. 4-B: November 20, 1937. Sequestrum is becoming absorbed. Fusion apparently not solid through mid-portion of joint.

FIG. 4-C

FIG. 4-D

FIG. 4-C: June 9, 1938. Sequestrum has become absorbed.

FIG. 4-D: January 10, 1939. Outline of destructive area in sacrum and ilium marked by sharp outline (healing). Joint completely fused above by bone.

non-specific metastatic osteomyelitis in several long bones. Her clinical course suggested a pyogenic infection rather than one of tuberculous origin. One biopsy specimen, taken from a draining sinus tract over the sacro-iliac joint, was interpreted initially as showing a mixed tuberculous-pyogenic infection, and the patient was admitted to the Sanatorium. Further review of this specimen failed to show positive evidence of tuberculosis. At no time was the acid-fast organism isolated.

Bacteriological proof of tuberculosis was obtained from sinus material in one of the remaining four patients. These patients had had roentgenographic evidence of destruction of the joint with or without sequestration (Figs. 3, 4-A, 4-B, 4-C, and 4-D), prior to complete or partial obliteration of the joints by osseous trabeculation. In no patient in the series was autopsy material available.

Thus seventeen patients had fusion of one sacro-iliac joint by bony ankylosis, which was either present at the time of admission or developed while the patient was under

observation. In fourteen (61 per cent.) the joints fused spontaneously without operative intervention.

Six patients (26 per cent.) showed no evidence of joint fusion. Of this group, two died early in the course of the disease; in two the infection is apparently quiescent without evidence of osseous union; and two show progressive narrowing of the joints without destruction.

The part played by secondary invaders in the promotion of bony ankylosis in any individual case is difficult to determine. However, the presence or absence of sinuses did not alter the apparent tendency of the joint to become obliterated by osseous union. (One patient with sinuses and two patients without sinuses had operative fusion of the joints.)

Patients with Sinuses		*Patients without Sinuses*	
Joint fused	4	Joint fused	13
Joint not fused	2	Joint not fused	4

In all but two of the cases reviewed, active tuberculosis was bacteriologically proved. The vast majority of the patients were seriously infected by the involvement of other organs; few of them entered a sanatorium because of active disease of the sacro-iliac joint alone. We have grouped the patients according to a classification similar to that outlined by Cleveland:

Group A. Patients with a healed primary pulmonary lesion, but no associated tuberculous involvement.
Group B. Patients with *only* associated active pulmonary disease.
Group C. Patients with no pulmonary disease, but with other active foci of involvement.
Group D. Patients with active pulmonary disease plus other foci.

Twenty-one of the twenty-three patients fall into *C* and *D* classifications (Table I). (In twenty of these patients, because of their generalized tuberculosis, operation was deferred, and thus they form an excellent group in which to study the terminal history of the local disease.)

TABLE I

Group	Total	Died	Living and Well	Living but Ill	
				Good Prognosis	Poor Prognosis
A	1		1		
B	1		1		
C	6	1	1	2	2
D	15	8	5	1	1
Totals	23	9 (39%)	8	3	3

DISCUSSION

It is impossible to make any definite conclusion as to the cause of the obliteration in the sacro-iliac joints. In all but two patients, tubercle bacilli were isolated from some lesion in the body. One of these two had a primary lesion, and in the other the disease process was apparently due to a widely disseminated pyogenic infection. In only four patients did material aspirated from the sacro-iliac lesion or from an accompanying abscess reveal acid-fast bacilli. In only one other was such a diagnostic test attempted. Thus these findings do not justify the definite conclusion that tuberculosis is the etiological factor in these cases. The presumptive evidence, however, is that these lesions are of tuberculous origin.

Patients with bilateral lesions were eliminated in order to rule out early spondylitis rhizomelica. In no patient did changes characteristic of this disease supervene throughout the entire follow-up period. The vast majority of patients (twenty-one) are in an age group

in which spontaneous obliteration of the sacro-iliac joint does not occur[2,3,7]. Although in many patients the joints became ankylosed while at complete rest, it is difficult to conclude that rest itself produced the change. If this were the primary factor, it is unlikely that selective obliteration of one joint would have resulted. This is particularly true where the obliterated joint showed an accompanying or antecedent destruction.

Thus the etiology lies between a low-grade pyogenic infection and one of tuberculous origin. In only one case was it felt that a pyogenic agent was the sole etiological factor. Even though in seventeen patients no material was obtained from the joint and no positive diagnosis was made, the presence of widely disseminated tuberculous lesions elsewhere in the body is strong presumptive evidence that the origin of this lesion is tuberculous. It is on the basis of this presumption that these findings are reported. It is hoped that further observations will be stimulated in order that a natural terminal history of sacro-iliac tuberculosis without operation may be recorded; and that, with larger series, the value of the operative treatment will become established.

Because of the relative rarity of the condition, alternate case comparison, similar to the work of Finklestein and his associates on Pott's disease, does not seem feasible.

Three patients who had operative fusion of their joints were included in this series in order to determine, if possible, whether the operation would be indicated from the point of view of lowering the period of hospitalization and convalescence. Operative fusion in this institution is used as a method of immobilizing and obliterating the joint after the infection appears to be under control, and not as an immediate form of therapy. The patients upon whom the operation was performed were in good general condition and demonstrated evidence of healing, both of the local and disseminated lesions. In contrast, those who had no operative intervention had, for the most part, widely disseminated tuberculosis and were in poor general condition. A comparison of the length of hospital stay would be a poor criterion, therefore, for the establishment of the efficacy of the fusion operation.

It was impossible to compare the earliest evidence of fusion in these two groups, for the operation itself so distorted the contour of the joint roentgenographically that accurate early interpretation was impossible. The authors feel, therefore, that no conclusion can be drawn in this small series as to the efficacy of the operation in shortening the convalescence and in promoting osseous union.

After those patients had been eliminated in whom the sacro-iliac joint was ankylosed on the initial roentgenogram, spontaneous fusion of the joints occurred in six patients while they were under hospital observation. The earliest fusion occurred approximately four months after the onset of symptoms; the longest interval required was approximately two years.

Should the interpretation of these findings be correct, it is the authors' feeling that a program based on approximately one year of conservative therapy should be instituted before operative fusion is contemplated. Should the sacro-iliac joint appear at the end of that time to be approaching what might be termed "fibrous ankylosis", bone-graft surgery could then be performed. It is the authors' impression that those joints which are obliterated by bone have a better chance of maintaining a permanent arrest of their tuberculosis.

Seddon has stated that his only criterion for fusion of this joint (for he is prone to accept "fibrous ankylosis" as a good terminal result) is a tendency for subluxation of the joint in the presence of marked destruction. Seddon and Strange, in their review of 176 cases of sacro-iliac tuberculosis, were able to analyze by late roentgenograms only fifteen patients who were not submitted to fusion operations. Of this group, eleven progressed to solid bony ankylosis of the sacro-iliac joint, four to what they described as "fibrous ankylosis". From this information they questioned the advisability of operative therapy. Conservatism in the handling of this problem has been concurred in by Langston and by Sisefsky.

CASE REPORTS

A. K., No. 562442. A white male, aged twenty-eight, was admitted to the Sanatorium on January 16, 1945 (Fig. 1). He had had pain in the lower back with sciatica on the left, nine years before admission. The symptoms had lasted one and one-half years and there had been no recurrence. Treatment had consisted of a sacro-iliac belt and osteopathic manipulations.

Associated lesions were tuberculosis of the right hip (proved bacteriologically), and moderately advanced pulmonary tuberculosis.

The patient's right hip fused spontaneously after immobilization in a hip spica. He was discharged as well from the Sanatorium in January 1947.

L. L., No. 271017. A white male, aged twenty-seven, was admitted in 1942. He had had pain and disability in the right hip for one year, but no symptoms referable to the sacro-iliac joints.

Associated tuberculous lesions: tuberculosis of right and left hip joints (the right was fused in 1946; the disease in the left developed in 1946); renal tuberculosis; healed rib and costochondral tuberculosis; lumbo-sacral Pott's disease (Fig. 2).

Left hip-joint disease developed after fusion of the right hip in 1946. The patient had early evidence of renal insufficiency. He has been immobilized in a hip spica since admission.

W. C., No. 396652. A white male, aged thirty-three, was admitted on February 5, 1937. Intermittent, ill-defined pain had been present over the right sacro-iliac joint for six months.

Associated tuberculous lesions: Pott's disease of the ninth, tenth, eleventh, and twelfth thoracic vertebrae; questionable transverse myelitis; tuberculosis of the right shoulder, with sinus drainage; bilateral tuberculous epididymitis and seminal vesiculitis; tuberculosis of the left kidney; and tuberculous urethral stricture (Fig. 3).

The patient died on February 7, 1941, from renal insufficiency.

A. H., No. 397580. A white woman, aged twenty, was admitted on February 23, 1937. Pain had been present in the right lower back for approximately eight months. She had received deep roentgenotherapy for a condition diagnosed as "sacro-iliac malignancy". An abscess was present without sinus over the joint.

Associated tuberculous lesions: a minimal amount of active pulmonary tuberculosis; tuberculous nephritis; tuberculous endocervicitis; and tuberculosis of the knee (Figs. 4-A, 4-B, 4-C, and 4-D).

Treatment consisted of frame immobilization. When the patient was last seen, in 1939, her non-protein nitrogen was slightly elevated. The knee had healed by fibrous ankylosis.

NOTE: The authors wish to thank E. W. Laboe, M.D., and Carl E. Badgley, M.D., for their assistance in preparing this paper; and John F. Holt, M.D., for reviewing and confirming the roentgenographic interpretations.

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BLADE-PLATE FIXATION IN NON-UNION AND IN COMPLICATED FRACTURES OF THE SUPRACONDYLAR REGION OF THE FEMUR

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The treatment of non-union and of some acute fractures of the supracondylar region of the femur is often extremely difficult by the usual types of fixation. In November 1946, at the Interurban Orthopaedic Society, Dr. Hugh Thompson described the use of the blade-plate (Moore-Blount) in a patient with an acute supracondylar fracture of the femur, upon whom he had operated in the fall of 1943. In August 1946, the authors used this method in the first of three cases, without knowledge of Dr. Thompson's experience, although with the realization that this type of fixation had been used in other clinics for supracondylar osteotomies. Dr. Thompson has kindly submitted his case, to be added to our cases, in this publication.

The method to be described is not advocated for all cases of fracture or non-union in the supracondylar region. It is indicated in those cases in which failure or difficulty is anticipated by the more generally accepted techniques. Although this procedure is not without hazard, we believe that in selected cases it has advantages over other types of fixation. This has been noted particularly in old cases of non-union with considerable osteoporosis of the condyles. The condyles are comprised of cancellous bone and are subject to osteoporosis of both the reflex and disuse types. Often in long-standing cases of non-union, the condyles are so soft that screws will not hold. Another difficulty in cases of non-union is the development of intra-articular adhesions in the knee joint. These may bind the short distal fragment so firmly to the tibial condyles that the long lever of the

FIG. 1-A

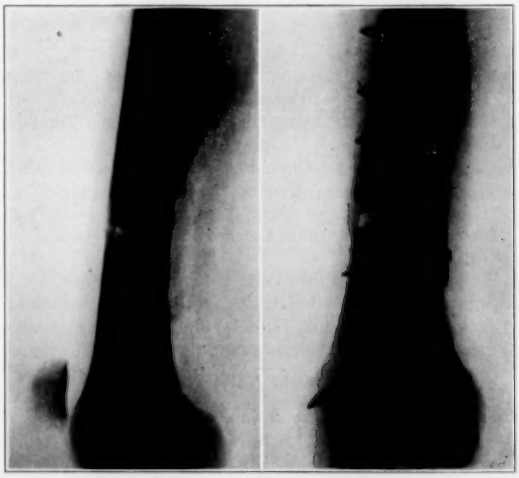

FIG. 1-B

Fig. 1-A: Case 1. Preoperative roentgenogram shows displaced supracondylar fracture.
Fig. 1-B: Postoperative roentgenograms reveal excellent alignment and fixation by blade-plate. Early callus is present.

leg causes motion to occur more readily at the fracture site than through the knee joint. Even with the extremity in a cast or in traction, this factor may prevent union or may allow malunion to develop.

The blade-plate method can also be used to advantage in T-shaped condylar fractures in which the condyles cannot be controlled by external means. Although some length may be lost by this technique, the advantages of normal alignment, rigid fixation, and early knee motion far outweigh this disadvantage. If other complications are present, such as intracranial lesions, multiple fractures, or senility, the use of the blade-plate will avoid confining the patient to bed. Its advantage in the aged is the same as in fractures about the hip in which this and similar types of fixation are in common usage.

TECHNIQUE

An anterolateral incision is made, so as to approach the lower third of the femur between the rectus femoris and vastus lateralis and through the vastus intermedius. The incision is

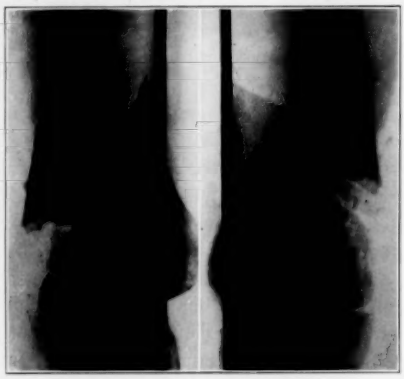

FIG. 2-A

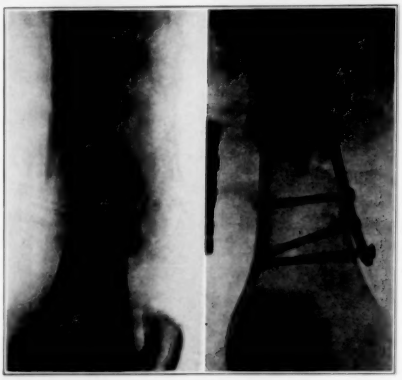

FIG. 2-B

Fig. 2-A: Case 2. Roentgenograms show compound, comminuted supracondylar fracture with loss of bone substance.

Fig. 2-B: Condition of fracture when seen by authors, six weeks after injury. Bone defect, inadequate fixation, and distraction are present.

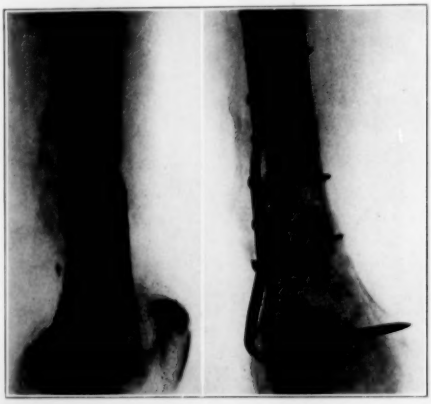

FIG. 2-C

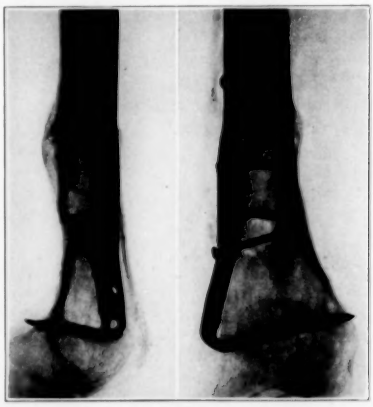

FIG. 2-D

Fig. 2-C: Roentgenograms show early callus and union, six weeks after blade-plate fixation.

Fig. 2-D: Eighteen months after blade-plate fixation.

carefully extended distally through the suprapatellar pouch and into the knee joint, the standard anterolateral incision of the knee being used. The lower third of the femur and the entire fracture site are exposed by subperiosteal disssection, the suprapatellar pouch being carefully stripped from the femoral fragments so that it can be completely and normally reconstructed in closure. If the fracture or non-union extends through the intercondylar notch, the condyles are first approximated by long screws or threaded pins. If non-union is present between the condylar fragment and the shaft, the scar and fibrous tissue are resected down to normal bone and the fragments are approximated, if possible, in an oblique plane or in the manner of a step-cut. If the condylar fragment is extremely short or if the metaphyseal portion is severely comminuted, it may be necessary to telescope the diaphyseal fragment a short distance into the condyles to assure maximum contact. Although some length may be lost, it may be well worth the sacrifice to obtain earlier and more certain union. After reduction has been obtained, the plate portion of the blade-plate is bent to conform to the lateral surface of the condyles and femur. The blade is driven across from the lateral surface, so that the shaped plate conforms exactly to the lateral femoral surface. At all times the blade-plate should be subsynovial and subperiosteal to ensure as little interference with knee function as is possible. When the plate has been screwed to the femur, one is impressed by the extreme rigidity of the fixation. At this point intra-articular adhesions, if present, can be cut. The synovial lining of the suprapatellar pouch and knee is carefully restored and closure is effected in layers.

FIG. 3-A

Case 3. Roentgenograms show comminuted T-shaped condylar fracture. An old depressed fracture of the lateral tibial plateau, with internal fixation, is present. Arthritic changes may be seen on tibial surface.

Early motion of the knee is encouraged as soon as the wound has completely healed. If necessary, in cases of non-union, motion may be started in balanced traction. In fresh fractures of the aged, early ambulation with crutches may be indicated to prevent pulmonary complications. Union should be solid in three to four months.

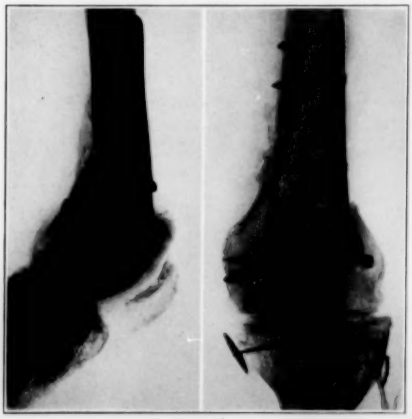

FIG. 3-B

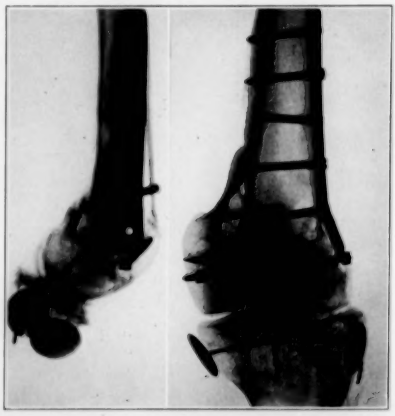

FIG. 3-C

Fig. 3-B: Three months after blade-plate fixation, union is solid.
Fig. 3-C: Condition of fracture twelve months after operation.

CASE 1*. In the fall of 1943 a man, twenty-two years old, had sustained a supracondylar fracture of the right femur (Fig. 1-A) and a fracture of the shaft of the left femur, in addition to severe head injuries which had produced unconsciousness for two weeks. The patient was seen by Dr. Thompson three weeks after the accident. At this time his mental condition had cleared, but little had been done for the fractures other than to protect them in Thomas splints.

Because it was considered unsatisfactory to keep both lower extremities in splints, the right femur was fixed by a blade-plate (Fig. 1-B). Dr. Thompson thought that a form of fixation was desired which would not require external support. The extremity was splinted for ten days, while the operative wound healed. After this time no form of external fixation was used, and the patient was encouraged to flex the knee while in bed. The patient obtained a fine functional result, with no deformity or disability.

CASE 2. On August 4, 1946, a man, thirty-nine years old, sustained a severe compound fracture of the lower third of the left femur (Fig. 2-A). A portion of the femoral articular surface had been lost through the open wound, as had a large bone fragment from the fracture site. The wound healed primarily, following débridement and plate fixation.

The authors first saw the patient on September 20, 1946, when roentgenograms disclosed non-union with loss of a large bone wedge from the fracture site posteriorly; the fragments had been distracted by the plate (Fig. 2-B). Exploration and fixation with a blade-plate were performed four days later. At operation, because of loss of bone substance, telescoping of the proximal fragment into the distal fragment was necessary. Rigid fixation was obtained by a blade-plate. Knee exercises in balanced traction were started early. Six weeks after operation, roentgenograms showed early union (Fig. 2-C). Motion was present from 180 to 160 degrees. Weight-bearing in a brace was started. Four months later union was solid and all support was removed. Active motion was possible from 180 to 160 degrees.

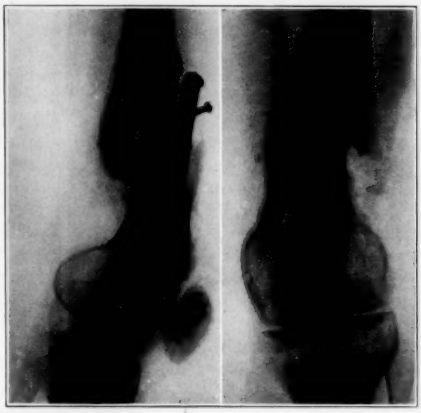

FIG. 4-A

Case 4. Roentgenograms at the time of initial examination show non-union with evidence of infection, sclerotic bone ends, loosened plate and screws, and a plate extending into the suprapatellar pouch.

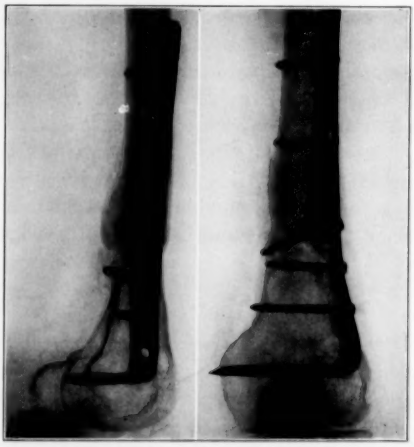

FIG. 4-B

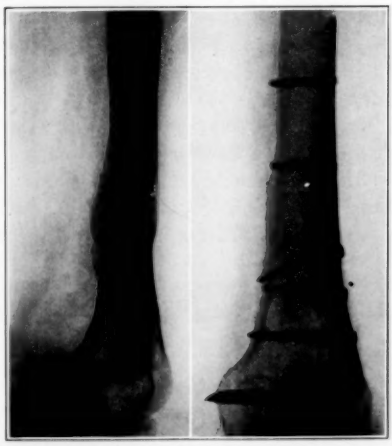

FIG. 4-C

Fig. 4-B: Two months after fixation with blade-plate, roentgenograms show early union with normal alignment.

Fig. 4-C: Five months after fixation, union is completely solid.

* Case of Hugh Thompson, M.D.

The patient was not seen again until a year later (Fig. 2-D). At that time he was completely free from pain. Active motion was present from 180 to 150 degrees, and there was an inch and a half of shortening. Limitation of motion was thought to be due to the partial avulsion of articular cartilage at the time of injury.

CASE 3. On October 19, 1946, a forty-year-old man sustained a comminuted T-shaped condylar fracture of the left femur (Fig. 3-A). Previously (in April 1942) he had suffered a depressed fracture of the lateral tibial plateau in the same knee; this had been operated upon elsewhere. Because of the arthritic changes in the knee as a result of the old fracture, open reduction with blade-plate fixation was elected to effect early joint mobilization and to restore the condylar relationship. Open reduction was done on October 25, 1946, and the condyles were approximated with two threaded pins, placed transversely. Because of severe comminution with small fragments, the proximal portion of the shaft was telescoped into the condyles. Blade-plate fixation was used. Knee exercises in balanced traction were started, and the patient was discharged with partial weight-bearing, six weeks after operation.

Solid bony union was present three months after operation (Fig. 3-B). Motion was present from 175 to 90 degrees. One year later there was motion from 180 to 75 degrees and one inch of shortening. The patient works in a lumber mill and his only discomfort is mild aching after sitting for long periods (Fig. 3-C).

CASE 4. A nineteen-year-old girl was first seen in January 1947, with an infected, draining, supracondylar fracture of the left femur, which she had sustained eight months previously. The fracture had been plated elsewhere and a postoperative infection had developed. The distal end of the plate had been placed in the suprapatellar pouch (Fig. 4-A). Frank non-union was present and the knee joint was infected. The patient's condition was toxic and she had a septic fever. After the administration of penicillin and many transfusions, the plate and sequestra were removed on January 3, 1947. The wound healed primarily. For three months the extremity was immobilized in a single spica. On May 2, with penicillin therapy, the knee joint and the lower third of the femur were explored through an anterolateral incision. Many intra-articular adhesions were found and sectioned. The bone ends were freshened in an oblique plane and fixed with a blade-plate. Knee motion was started in a hinged Thomas splint. The patient was discharged one month after operation in a toe-to-groin brace; passive motion was possible from 180 to 150 degrees (Fig. 4-B). Five months after operation the brace and crutches were discarded, as the roentgenograms showed solid bony union (Fig. 4-C). Eight months after operation the knee was completely free from pain. She had passive motion from 180 to 95 degrees and active motion from 165 to 95 degrees. Three-quarters of an inch of shortening was present. The patient thought she was still improving.

CONCLUSIONS

Blade-plate fixation in selected cases of non-union and of complicated fresh fractures of the supracondylar region of the femur has definite advantages, including rigid fixation, early joint mobilization, and, in the elderly, early ambulation with crutches.

The four cases presented illustrate the use of the blade-plate in cases of:

1. Simple supracondylar fracture complicated by multiple other fractures and head injury;
2. Comminuted non-union or prospective non-union, complicated by the loss of bone substance at the fracture site;
3. A comminuted T-shaped condylar fracture with rotation of the condyles, considerable comminution, and arthritic changes as a result of a previous fracture;
4. Old infected non-union with intra-articular adhesions and infection of the knee joint.

THE SYNOVIAL MEMBRANE OF THE KNEE IN PATHOLOGICAL CONDITIONS

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Translated by Emanuel B. Kaplan, M.D., New York, N. Y.

The surgeon who opens the knee joint finds frequently that changes have occurred in the synovial membrane. The membrane may be excessively thickened, or it may present changes in color and appear pink, red, or purple. In other instances its character may be changed, and the scalpel cuts into resistant elastic tissue instead of the ordinary soft synovial membrane.

Gross inspection does not permit one to appreciate the nature of the changes. The anatomical studies of Testut, Poirier and Charpy, Mouchet, and Lévêque do not furnish any information on the importance of the synovial membrane, on its precise topography, or on the distribution of the synovial folds. For example, it is impossible to learn the average weight of the infrapatellar fat pad. This is easy to understand, because the synovial membrane is an unstable organ, varying according to the age and obesity of the individual and depending upon conditions at the time of observation (whether in motion or at rest, with static or distinct pathological factors).

Only microscopic studies, in our opinion, can help us to understand the pathological conditions.

NORMAL SYNOVIAL MEMBRANE

The histology of the normal synovial membrane was a subject of investigation by Hammer and by Braun toward the end of the nineteenth century. In recent years it has been studied by Efskind, Franceschini, Granel, Key, Kuhns, Magnus, Marquort, Mayeda, Policard, Raszeja, and Rouvière. Numerous problems were involved, concerning especially the aspect of the cells covering the articular wall, their role, and their origin. It now appears to be accepted that:

1. The synovial membrane is derived from the mesenchyma; it is neither epithelium nor endothelium.

2. The functions formerly attributed to it, such as filler of the joint, source of reserve fat, and protector from injury in motion, are of secondary importance. The synovial membrane functions actively in a manner similar to that of the reticulo-endothelial tissues.

3. The varying morphology of the synovial membrane, with some zones rich in cells and others with few cells, represents only an adaptation to mechanical or pathological conditions.

The author has adopted the histological classification suggested by Key. The various aspects of the synovial membrane are not classified as to the number of surface cells, but according to the nature of the subjacent layers. Key divided them into: (a) an adipose type, covering the articular fat pads; (b) a fibro-areolar type, overlying areas subjected to moderate pressure and pull, which are the principal sites of villi; and (c) a fibrous type, covering ligaments and tendons. We could add to this group a *muscular* type, covering the suprapatellar pouch. In the present study, special attention has been given to the infrapatellar adipose type, for many reasons:

In the course of an operation, it is easy to remove a piece of the infrapatellar fat pad. The site of the removal is fairly constant. The adipose synovial membrane appears to be affected early by the pathological process; all surgeons have observed an enlargement of the infrapatellar fat pad in affections of the menisci. Finally, in examining the fat, which is the most ordinary tissue of the joint, we can easily confirm the reactions of the synovial membrane.

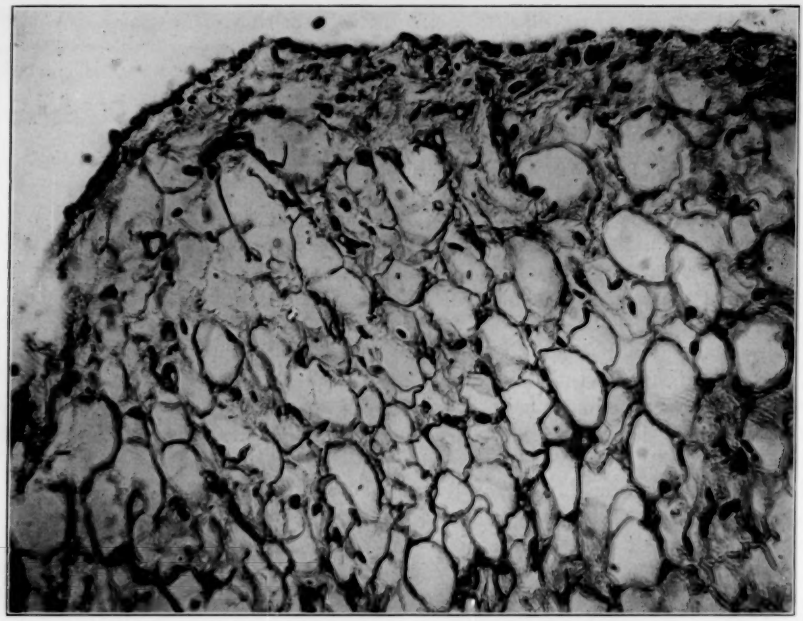

FIG. 1
Adipose synovial membrane of a stillborn infant (× 250).

Observations in Normal Man and the Normal Animal

The observations in this study confirm the description of Key. The adipose synovial membrane consists generally of a single internal layer of cells, resting on an external adipose layer (Fig. 1). The cells of the intima are flattened out, fairly well spaced, and separated by an interstitial, homogenous, non-fibrillar substance which shows the characteristic staining reactions of collagen. The external layer is formed by typical adipose tissue, crossed by fine collagenous fibers. Small capillaries, by joining the two layers, form a wide-meshed network. A few larger vessels are seen in the external layer.

The findings just described are also found in the rabbit (Fig. 2).

In certain preparations the intima has a multistratified appearance, as a result of obliquity of the section. The articular border, instead of being continuous, may be lacelike. Sometimes the cells and the intercellular substance seem to separate and to fall into the articular cavity; this is a true process of desquamation.

In some adults the adipose mass of the external layer is not uniform (Fig. 3). Fine collagenous fibrils may be found between the fatty vesicles; accumulations of fibrocytes and numerous vessels are also present. The presence of connective tissue in the adipose mass is considered a sign of aging. It will be necessary to differentiate this condition from true pathological fibrosis. Finally, it may be noted that free cells are rare in the adipose synovial membrane, although occasionally a plasmocyte or lymphocytes may be encountered.

PATHOLOGICAL CHANGES IN THE SYNOVIAL MEMBRANE

To understand the behavior of the synovial membrane in pathological states, we excluded from this study all diseases affecting the diarthrodial cartilage or bone (such as osteo-arthritis or chondromatosis), and those due to micro-organisms (tuberculosis or septic arthritis) or to tumors.

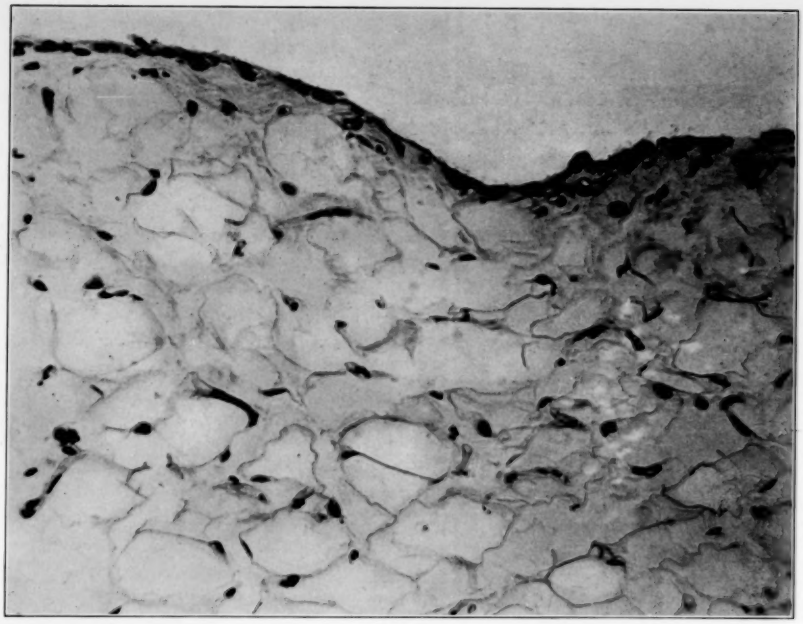

FIG. 2

Normal adipose synovial membrane of a rabbit (× 250). The intima consists of elongated connective-tissue nuclei, irregularly arranged in the free border; the basal substance is amorphous. The external layer contains typical fat tissue.

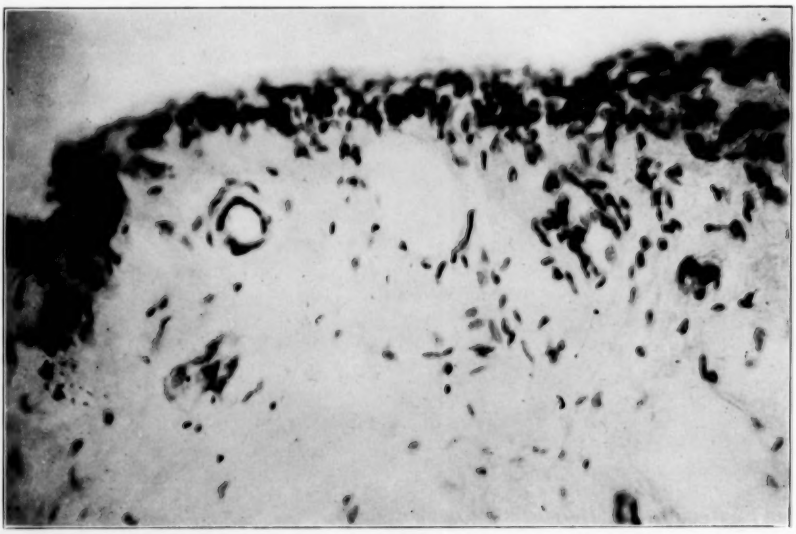

FIG. 3

Adipose synovial membrane of a young adult (× 250). Mild fibrosis of the adipose layer is present. The density of the nuclei of the intima is due to the obliquity of the section. There is desquamation of the cells of the free edge.

I. *Rupture of the Menisci*

Review of Literature

Roux of Lausanne, in 1895, maintained that there is a disease of the menisci,—namely, meniscitis. He found, in 1926, an irritative infiltration (*"infiltration réactionnelle"*), overlying the border of the meniscus.

Patry of Aarau (Switzerland) supported an analogous view in 1926. He stated that the histological examination of pieces of degenerated (*modifié*) synovial membrane confirms the existence of a chronic inflammatory process with infiltration of migratory cells, connective-tissue proliferation, and hyperaemia with vascular neoformation.

Bircher, in 1933, noted that changes of the meniscus affect the fat pad equally, qualitatively and quantitatively, and he wondered what relation could exist between the lesion of the meniscus and that of the synovial membrane.

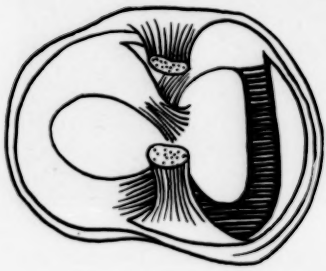

FIG. 4-A

Fig. 4-A: Bucket-handle tear of the medial meniscus of forty-eight days' duration in a miner, thirty-five years old. Drawing of medial fibrocartilage with separation of a large portion, adherent to the anterior and posterior horns and displaced toward the interior of the joint. The lines indicate the portions of the anterior horn and of the meniscus which were removed.

Fig. 4-B: Photograph of the specimen removed.

FIG. 4-B

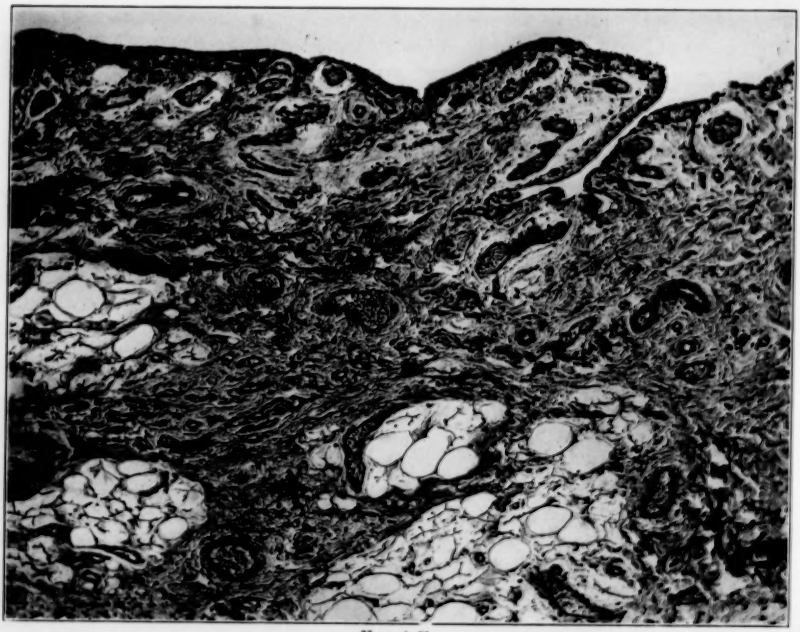

FIG. 4-C

Adipose synovial membrane (× 75) with marked fibrosis, many cells, and many vessels. The outermost layer constitutes a thick-walled partition. Note the villus.

FIG. 4-D

Detail of Fig. 4-C (× 250). Shows multistratified intima. The external layer is fibrous, very vascular, and notably without fat. Little or no leukocytic infiltration is seen.

Two isolated reports, one published by Estor in 1934 and the other by Morasca in 1936, concern perimeniscitis and mention the reaction of the synovial membrane. Ceelen, in 1936, considered the repair of meniscal lesions and mentioned also the synovial membrane.

These are the only contributions we have found in the Continental literature. Since the meeting of the *Congrès Français de Chirurgie* in 1926, the theory of inflammatory meniscitis has not been recognized in Europe.

Of the literature in the English language, the article by Bristow in 1925 is noteworthy, because he presented the problem without giving a solution. A photomicrograph is reproduced to illustrate the "synovial membrane from an average case of internal derangement, showing the endothelial lining, an average number of blood vessels and the fibrous tissue stroma". This contrasts with a second photomicrograph, taken from a case of hypertrophic villous synovitis. The author emphasized the need for a more detailed histological study.

Wallace and Permar, in 1927, found that the injured meniscus acts as a foreign body; the synovial membrane reacts by proliferation, assuming the aspect of aseptic inflammation with congestion, serous exudate, cell proliferation, and constant presence of some inflammatory cells. Over the fat pad especially, the adipose cells are atrophic, marked fibrosis develops, the vessels increase in number and thickness, and diffuse "pericapillaritis" appears.

Bick, in 1930, observed changes characteristic of subacute synovitis.

Burman and Sutro, in 1933, observed incidentally in their study of meniscal degeneration: "The synovia showed frequent changes, consisting of hyperplasia of varying degree, congestion of subsynovial capillaries with a varying amount of lymphocytic infiltration, and occasional vessel alteration, as hyalinization".

In experimental studies on healing of torn or removed menisci, by Niessen, King, and Azzollini, the synovial membrane was examined only incidentally.

FIG. 5-A

FIG. 5-B

Observations in Man

We removed parts of the infrapatellar fat pads for biopsy in the course of meniscectomies. The material was classified according to the length of time since onset, as follows:

Evolution of Less than a Month:

If the patient is operated upon a few days after the accident, only a few histological changes are observed in the adipose synovial membrane. Slight activity of the villi may be observed, a slightly more intense vascularization, a discrete fibrosis of the adipose tissue, and the appearance of fibrocytic elements around the vessels. In view of our statement on changes in connection with aging, however, it is impossible to state that the picture is truly pathological.

Evolution of Average Duration:

The intima shows an irregular wavy border with large villi in some areas. It consists of two to

Fig. 5-A: Tear of the lateral meniscus with a transverse fragment. Tear was of thirty-four years' duration, in an individual forty-nine years old. The fragment arises from the posterior portion of the fibrocartilage and protrudes transversely into the joint.

Fig. 5-B: Drawing of the meniscus, removed *in toto*.

FIG. 5-C

The internal layer of adipose synovial membrane (× 75) is very dense; the intermediary layer consists of a band of connective tissue with lamellae parallel to the surface; the external layer is more fibrous than adipose. The ligament is adipose in one area.

five layers of nuclei, varying in form and distributed irregularly. The intercellular substance consists of a network of poorly defined fibrils, bordering irregular alveoli which

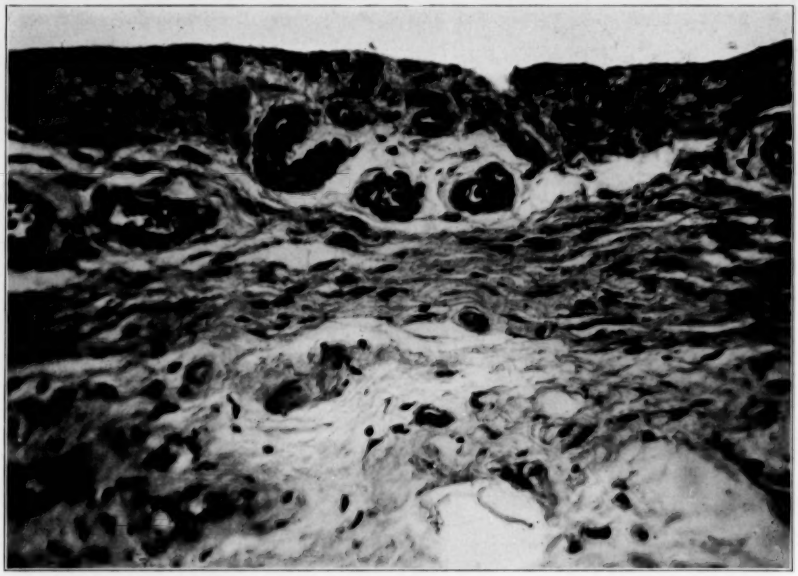

FIG. 5-D

Detail of the preceding section (× 250). The internal layer shows numerous nuclei, very dense stroma, and fairly large subjacent arterioles (due to hypertrophy of their muscle elements). The intermediary layer is a fibrous band with elongated nuclei parallel to the surface, rare vessels, and no important infiltration. The external layer shows almost complete disappearance of fat cells.

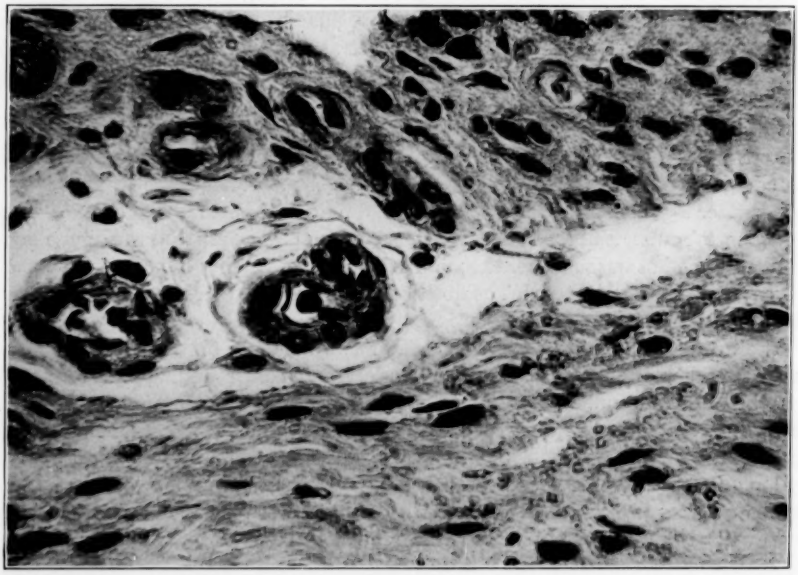

FIG. 5-E

Detail of preceding section (× 625).

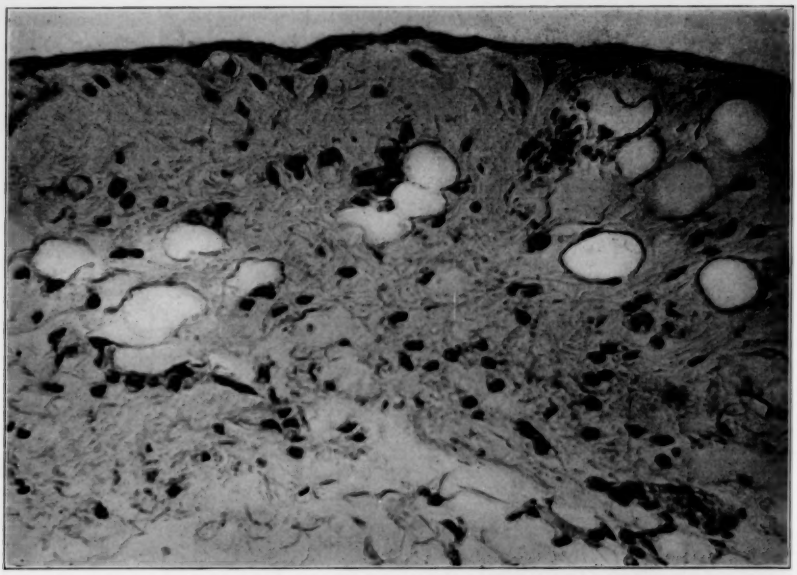

FIG. 6

Forty-two days after an experimental meniscal injury in a rabbit (× 250). The internal layer has a fair number of nuclei with a dense stroma between them. The external layer also shows fat vesicles, but the fibro-areolar picture predominates; the cells are mostly connective and the free cells are rare. In the right upper quadrant an area of erythrocytes may be seen.

appear empty. At the articular surface, these fibrils appear to be crowded into a thin unraveled line. The thinner and less numerous capillaries are distributed near the surface; the larger and more numerous capillaries are located deeper.

The external layer is heavily laden with irregular bands of connective tissue which surround the fat lobules or vessels and which penetrate into the villi. In the vicinity of some of the vessels, a few lymphocytes are found. Plasmocytes are rare (Figs. 4-A to 4-D).

Evolution of Long Standing (More than Six Months):

In low-power magnification, a surprising fibrosis of the fat tissue is seen. This fibrosis has undergone some organization: The connective-tissue lamellæ are arranged parallel to the surface so well that three layers can be differentiated,—an internal layer, as in all synovial membranes, a fibrous intermediary layer, and an external fibro-adipose layer.

The intima has irregular borders; villi are rare. The number of nuclei vary from two to seven; they are round or oval. The fibrils of the intercellular stroma are more numerous and closer than normal. Capillaries are seen frequently.

The intermediary layer consists of one or two bands of fibrous tissue with lamellæ arranged parallel to the surface. The nuclei are elongated. Surrounding some of the vessels is a crown of small round cells. In the majority of cases, the number of plasmocytes is not greater than that found in the normal synovial membrane. Rarely, their number is increased, but then the history of the patient shows some complication, such as locking of very long duration, obesity, genu valgum, or pre-existing arthritis.

The external layer is more adipose than fibrous. Between the fat lobules are large fibrous walls, similar to the tissue of the intermediary layer (Figs. 5-A to 5-E).

Observations in the Animal

Removal of the medial meniscus was performed on the right knees of eight adult

rabbits. The animals were operated upon under anaesthesia. The joints were closed aseptically, and the wounds healed readily.

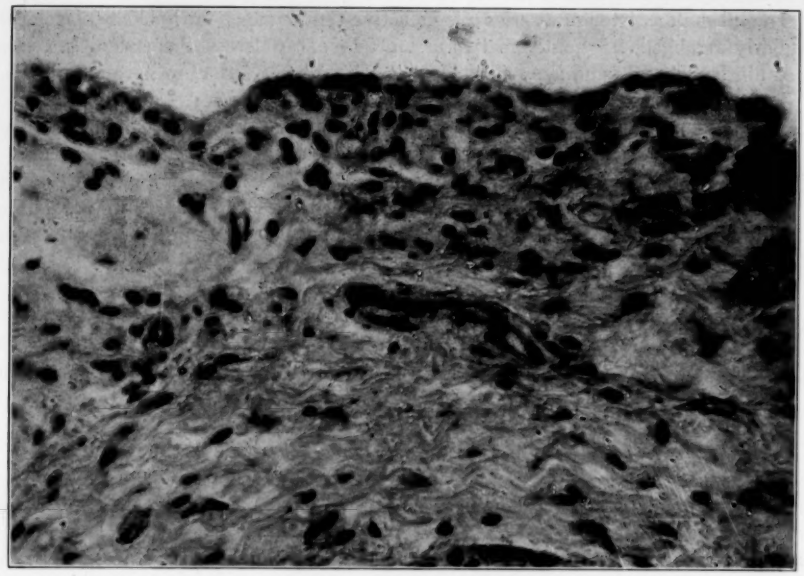

FIG. 7

One hundred and two days after an experimental meniscal lesion (× 250). Note irregularity of the articular edge. The intima is directly continued into the external layer. All trace of fat has disappeared. Compact fibro-areolar tissue is present with large vessels. The majority of cells are fibrocytic in character.

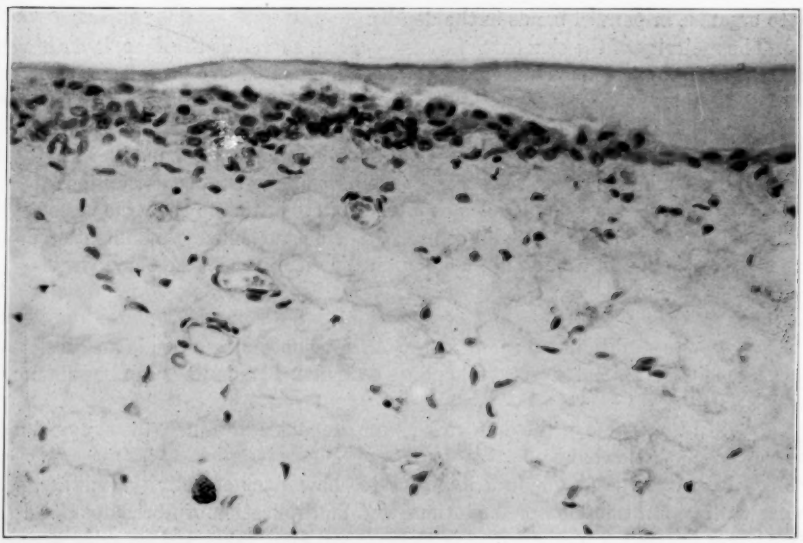

FIG. 8

Section from rabbit, sacrificed 231 days after a meniscal injury (× 250). An amorphous substance has been deposited at the edge of the synovial membrane. The internal layer is multistratified. The external layer is fibro-adipose.

Evolution of Average Duration (More than One Month):

Two rabbits were sacrificed on the forty-second day. The fat pad of the right knee was removed, and also that of the sound left knee, for comparison.

The intima consisted of a series of connective-tissue nuclei, fairly close to each other, irregularly arranged, frequently in two or more layers. Between them were fine, closely placed fibrils. The villi and synovial folds were more marked than in normal animals.

The external layer was mostly fibrocellular. In some areas it was adipose, but the vesicles were small and deformed. The predominating intercellular stroma consisted of collagen fibers of variable density, sometimes collected in bands. As in the intima, the majority of cells had the characteristics of fibrocytes. A few mitotic figures were noted.

The number of plasmocytes and of mononuclear leukocytes was reduced and usually did not exceed one cell per field. The large and small vessels were numerous and were filled with red blood cells (Fig. 6).

Evolution of Long Duration (More than Seventy Days):

The other animals were autopsied between the seventieth and the two hundred and thirty-first days. The histological findings (Figs. 7 and 8), which were practically identical, can be summed up as follows:

1. Increase in number and importance of folds and villi.
2. Collection of fibrinoid substance adherent to the surface of the membrane.
3. Irregularities and desquamation of the intima. The border has an indented appearance with "dropping" of some elements into the joint and unraveling of the basal substance.
4. Hypertrophy of the internal layer; nuclei are thrown together, arranged in two or more irregular strata. Stroma are thickened and dense, with fine fibrils. Several capillaries are seen.
5. Disappearance of the adipose tissue from the external layer. In some spots the original outline can be recognized; it is replaced almost everywhere by a fibro-areolar or even by a fibrous texture. Collagenous fibers, which are rare on the surface, have a tendency to organize in parallel bands in the depths.
6. The majority of the elements of the superficial, as well as the deep, layer have the character of fibrocytic cells. Their appearance is varied. The surface cells are ovoid and somewhat swollen; at times they look like small round cells, grouped closely in the external layer. These free histiocytes are rare.
7. Inflammatory cells, plasmocytes and mononuclears, are equally rare. Exceptionally, the plasma cells are collected in groups, resembling nodular formations.
8. The blood vessels, ranging from capillaries of the intima to the large vessels of the deep layer, are filled with many red blood cells. There is no leukocytic infiltration or connective-tissue reaction in the form of a crown in the vicinity of these blood vessels.

Conclusions

The processes studied in man confirm the observations in the animal (the acceleration of the process in the animal must be taken into account). The findings can be summarized as follows:

Stage I: In the course of the first weeks after the meniscal injury, the synovial membrane shows very little change.

Stage II: After the first month it begins to show signs of activity (villi, irregular articular outline, stratification of the intima, and multiplication of fibrocytes), and then of progressive sclerosis (disappearance of the external fatty layer and its substitution by fibrous tissue).

Stage III: Toward the sixth month in man and the third month in the animal, the processes described become more intense, especially the fibrosis, which has a tendency to

organize and to become lamellated. This picture persists as long as the meniscal injury is present.

In certain cases a new factor, rather discrete, may be added,—namely, differentation of plasma cells and mononuclears.

These histological facts are important to the orthopaedic surgeon, since they indicate:

1. That the fat pad is actually enlarged in meniscal injuries.

2. That its structure is changed. It is understood that the fat is not crushed when grasped by the forceps, but rather grates when cut by the scalpel.

3. That the meniscal injuries which are not operated upon have no tendency toward repair, but show progressive anatomical disorders.

4. If plasmocytic and mononuclear infiltration is accepted as a sign of chronic arthritis, it is possible to state that irritation of the joint by meniscal injury sometimes produces eventually a moderate chronic arthritis.

5. That the theory of the followers of Roux, that meniscitis or perimeniscitis is a preexisting lesion, cannot be defended. The processes of infiltration found in the synovial membrane are the late results of trauma and not a predisposing cause. The synovial disorders which follow a meniscal injury are of mechanical nature, similar to the mechanical nature of osteo-arthritis following an unreduced congenital luxation of the hip.

II. *The Hemarthroses*

Review of Literature

Effusions of blood into the joint are frequent, but histological studies of the synovial membrane in effusions of blood are rare. Only one clinical observation, that made by Franceschini in 1929, has been found. He made histological sections from a fragment of human synovial membrane, removed in the course of a surgical procedure from a patient with a simple hemarthrosis.

From an experimental viewpoint, if we omit some early observations made by Riedel, Jaffe, and Seeliger, who did not study the synovial membrane but rather the coagulation of blood in the joints, only one paper, that published by Key in 1929, actually considers this subject. Under the title of "Experimental Arthritis", he studied the action of "mild irritants" in three series of rabbits. In the first series, the animals each received a single injection of citrated rabbit blood; in the second series, each animal received seven injections of blood in a period of three weeks; in the third group, each animal received a single injection of India ink. The duration of observation was twelve days.

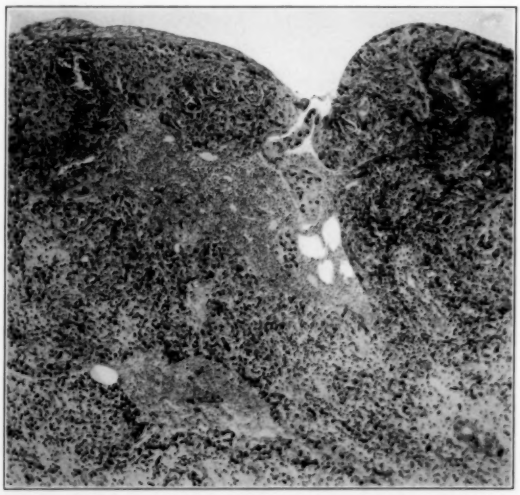

FIG. 9

Fourth day after fracture of the patella, showing adipose synovial membrane (× 60). In the upper portion, two large villi enclose a collection of erythrocytes. In the lower portion, an island of red blood cells is found in the hypertrophied intima. The external layer (not reproduced) is normal.

Only the first two groups will be considered here. Irrespective of the number of injections, Key noticed a sudden increase of cells in the articular fluid, which disappeared progressively in twelve days. In the first forty-eight hours most of the nucleated cells were

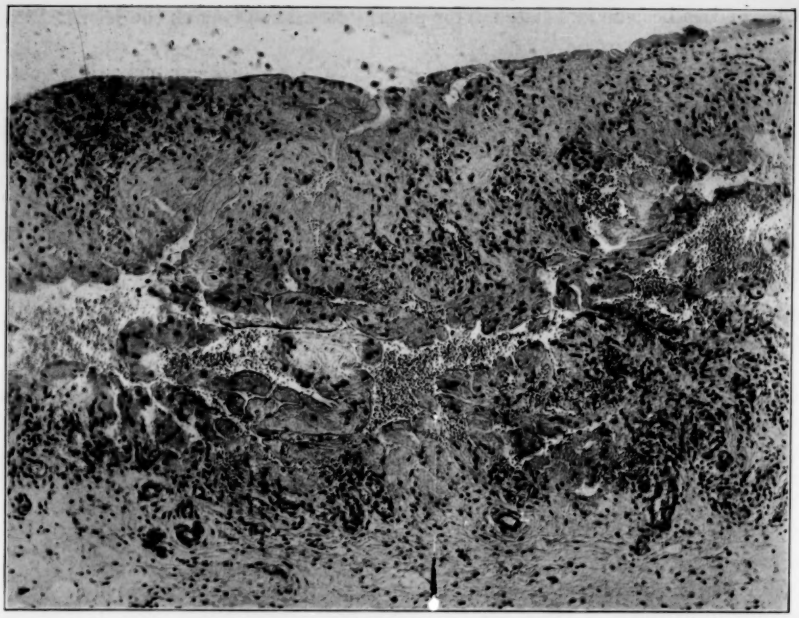

FIG. 10-A

Seventh day after fracture of the patella. Photomicrograph (× 75) of adipose synovial membrane represents the intima only; its thickness can be observed. It differs greatly from the normal (Fig. 1). The synovial fringe is flat. The villi are fused. Toward the lower portion there is a zone of transition with the external layer. This layer (not represented here) has its usual adipose character.

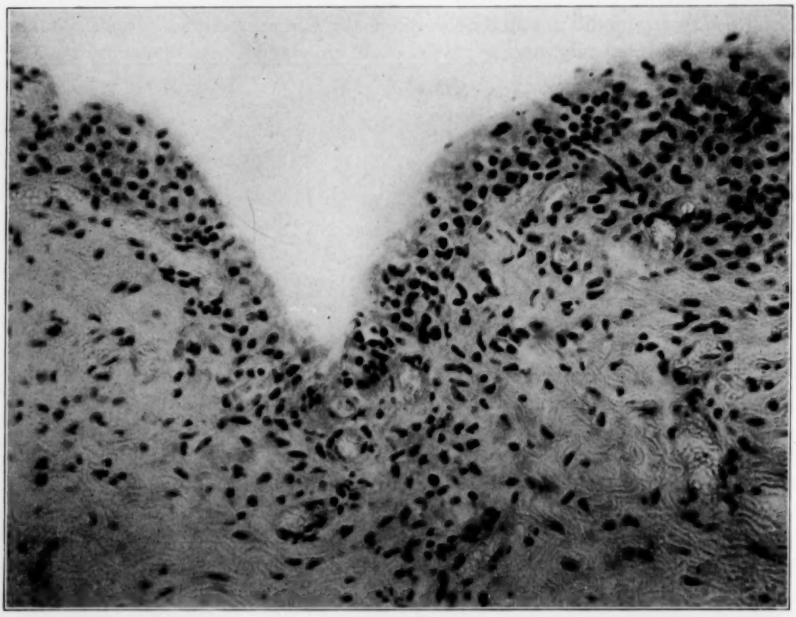

FIG. 10-B

Another aspect of the same preparation (× 250). Multistratified intima is forming a pseudo-epithelium.

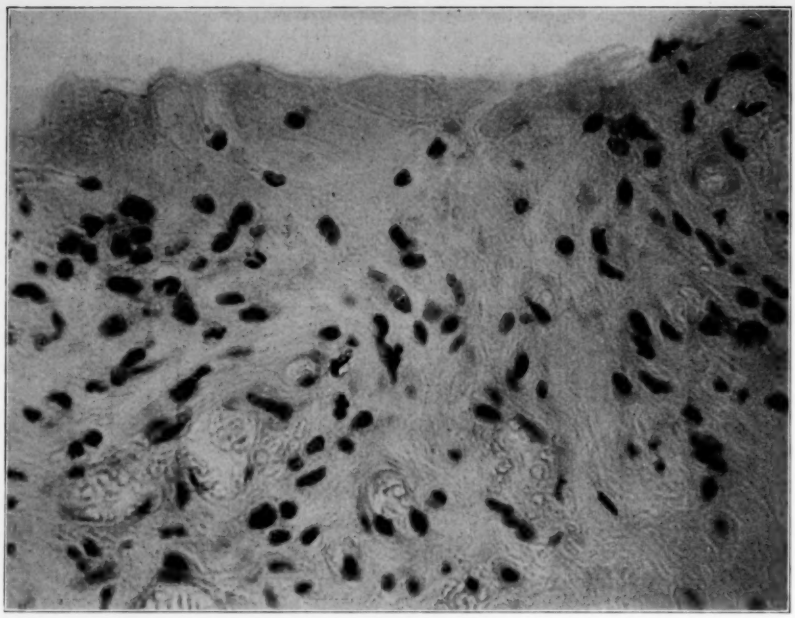

FIG. 10-C

Detail of Fig. 10-A (× 500). The histiocytes of the edge have disappeared, but deeper hypertrophic histiocytes are found. A few inflammatory cells and dilated vessels are present.

leukocytes; following this the macrophages predominated. After a single injection, section of the synovial membrane showed slight proliferation of the superficial cells and infiltration of the subsynovial layers by leukocytes and macrophages. The tissue became normal after the sixth day. Key stated that the red blood cells can leave the joint: "(1) through the sheath of the tibialis anticus muscle; (2) by being carried out by the macrophages (clasmatocytes); (3) by passing between the cells of the synovial membrane; and (4) by being incorporated in the synovial membrane in instances where the blood cells are held in fibrin clots".

A few days after the seventh injection, Key noticed an increase in the number of cells in the articular layer as well as in the deep layer, also an abundance of red blood cells (in resorption), leukocytes, and macrophages. The villi were very well developed. These changes were especially important over the fat pad. Subsequently the infiltration decreased, but on the twelfth day after the last injection the synovial membrane had not returned to normal; the villi and folds persisted, the deep layer was multistratified, and the subjacent zones retained a very cellular structure with collagenous fibers. The vessels were numerous. Key commented: "Whether or not this slight fibrosis of the subsynovial tissues is permanent has not yet been determined".

Observations in Man

We have obtained pieces of the infrapatellar fat pad during the course of operations for fracture of the patella or avulsion of the tibial spine. Many biopsies were made between the fourth and the sixty-first days. The changes observed occurred only in the intima. The outer layer, on the contrary, remained fatty with only occasional fibrosis.

A. *From the first days* (Fig. 9) the villi showed an extraordinary exuberance; their ends met and adhered to each other, forming little lakes filled with red blood cells.

The intima, considerably thickened, was very rich in histiocytes, polymorphonuclear

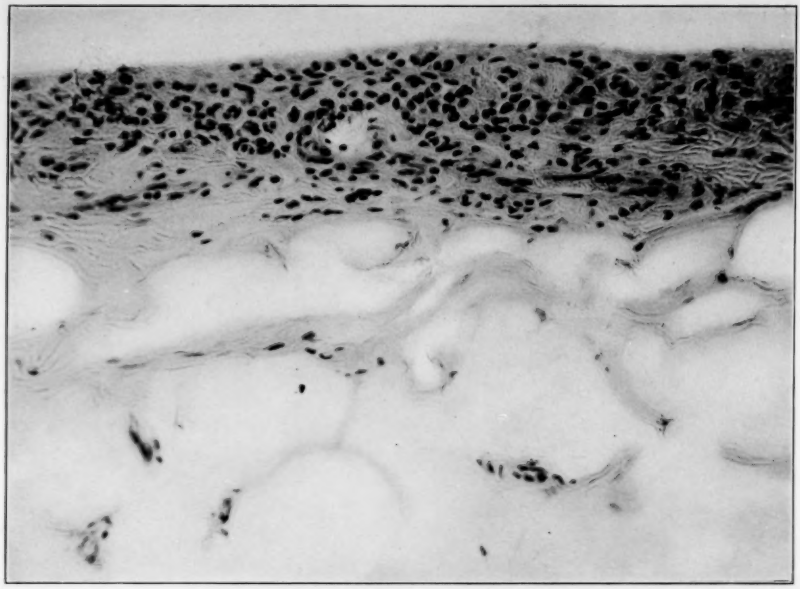

FIG. 11

Adipose synovial membrane (× 250), sixty-first day after fracture of the tibial spine. The articular edge is normal. The intima contains intracellular pigments (not visible in the reproduction). The external layer is normal and there is no infiltration.

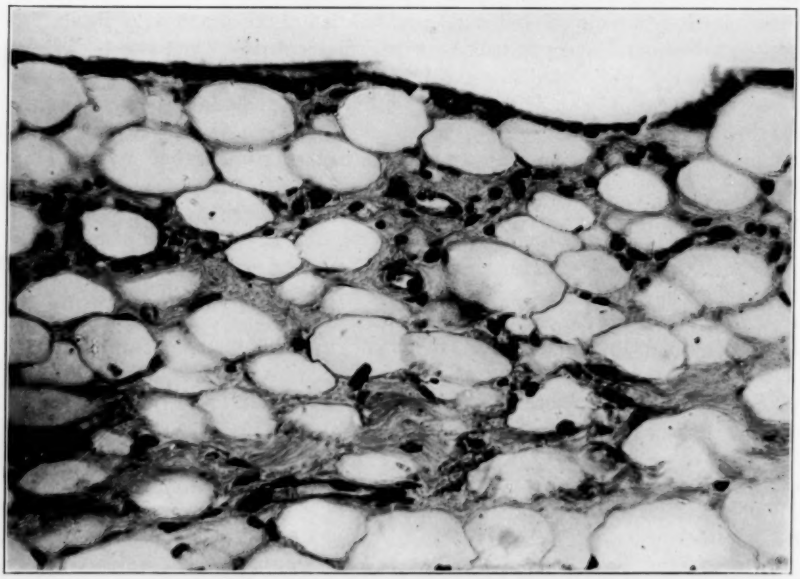

FIG. 12

Ten injections, each of one cubic centimeter of blood, were given in a period of one month. The rabbit was sacrificed two months after the last injection. The synovial membrane (× 312) regains its adipose structure. There are only a few fibrous tracts. The free cells are rare and the pigments have disappeared.

neutrophils, and monocytes. The basal substance showed a network with wide spaces, the result of oedema. The dilated vessels showed leukocyte margination.

B. *At the end of the first week*, there was still hypertrophy of the internal layer, in contrast to the normal aspect of the external layer. The villi were fused at the tips, surrounding islets of red blood cells. A smooth synovial surface reappeared (Fig. 10-A).

The intima was thickened and showed a variable structure. In certain areas the histiocytes, which normally represent only a single interrupted layer of cells on the surface, were increased in number (as confirmed by the presence of mitosis), and became stratified, constituting a pseudo-epithelium. The cytoplasm of the most superficial cells was vacuolized, and then these cells became desquamated into the articular cavity and dissolved (Fig. 10-B). In other areas the basal substance was in direct contact with the articular cavity, as if the histiocytes which covered it had completely disappeared (Fig. 10-C).

The islets of red blood cells, surrounded by fused villi, showed little change and hardly any leukocyte infiltration. The plasma was partly clotted, forming shreds which adhered to the denuded basal substance. A discrete infiltration of polymorphonuclear neutrophils and lymphocytic cells appeared around the small vessels.

The outer layer, which was typically adipose, was not infiltrated.

C. *At the end of the second month*, the synovial membrane had assumed an almost normal aspect. The intima presented a normal articular border. The histiocytes formed a multistratified layer. These were intermixed in the depths with lymphocytes and plasmocytes. Iron pigments could be detected inside and outside the cells, by the reaction of Perles (Fig. 11).

Observations in the Animal

Under ether anaesthesia, one cubic centimeter of blood was aspirated from the ear of a rabbit into a syringe, previously treated with sodium citrate, and injected aseptically into the right knee. This procedure was repeated ten times within thirty days. The rabbits were sacrificed between the twelfth and the two hundred and twenty-second day.

On the twelfth day the articular line showed very well developed villi and marked synovial folds. The intima showed more cells than the normal side; the nuclei of fibrocytic character were also larger, with the oval form predominating. The stroma, instead of being amorphous, enclosed collagenous fibrils parallel to the surface. In many areas the border had indentations, as a result of the process of desquamation.

The external layer had lost its typical adipose character. There were still a few fat-filled spaces, but they appeared small and elongated, as if compressed by the fibro-areolar tissue which had replaced them; the fibers of this tissue were slender in the superficial portions and fasciculated in the deep layers. The fibrocytes were considerably increased in number and were enlarged; their form, although variable, was often ovoid. In addition, many free elements were found in the intima and in the deep layers,—histiocytes, plasmocytes, and some mononuclear cells, as well as pyknotic nuclei.

Iron pigments (identified by the technique of Perles) were first visible on the surface in the intercellular spaces and histiocytes, and also deeper in the interior of the free elements. Our illustrations are identical with those published by Key.

At the end of the second month a very marked regression of the process was noted (Fig. 12). The intima, still thickened, was formed by two layers of smaller fibrocytic nuclei. The villi had become more discrete. The internal border was less fringed.

The external layer was mostly adipose. There were only a few collagenous collections, mostly on the surface. The histiocytes had regained normal size and did not contain any iron pigments, as verified by Perles' technique. Practically no free red blood cells or mononuclear cells were present, but a few plasmocytes and pyknotic cells.

By the end of the sixth month the findings had become normal. The adipose synovial membrane of the experimental right side and that of the left side were identical and normal.

Conclusions

Effusion of blood into a joint produces immediate, very intense proliferative reactions in the synovial membrane. The processes take place almost exclusively in the intima, but the changes are only temporary and regress rapidly. The synovial membrane gradually becomes normal, and no indication of the process remains.

This experimental study permits an answer to the question of Key: The fibrosis is temporary. From a practical point, an effusion of blood into a joint is an incident without future repercussions. In the normal subject (we did not consider the complex problem of hemophilia), hemarthrosis does not lead to chronic arthritis.

We believe that aspiration of traumatic hemarthroses or removal of clots in the process of osteosynthesis of the patella is still indicated. It is done only to accelerate the normal process of healing, and not to avoid definitive lesions. We must also know that the blood which accumulates in a joint in the course of an arthroplasty or capsular repair is not directly responsible for possible future disturbances, such as recurrence of ankylosis, stiffness, or arthritis.

III. *Chronic Hypertrophic Villous Arthritis*

Review of the Literature

The French surgeons in the beginning of this century had foreseen the therapeutic possibilities of synovectomy for villous arthritis of the knee joint; Mignon and Lucas-Championnière prepared precise clinical and histological descriptions. After the first descriptions, however, the condition was neglected on the Continent.

The credit for reviving and continuing the subject belongs to the American school (Jones, Steindler, Swett, Speed, Henderson, and many others since 1924) and later to the German school (Payr, Burckhardt, and Mandl).

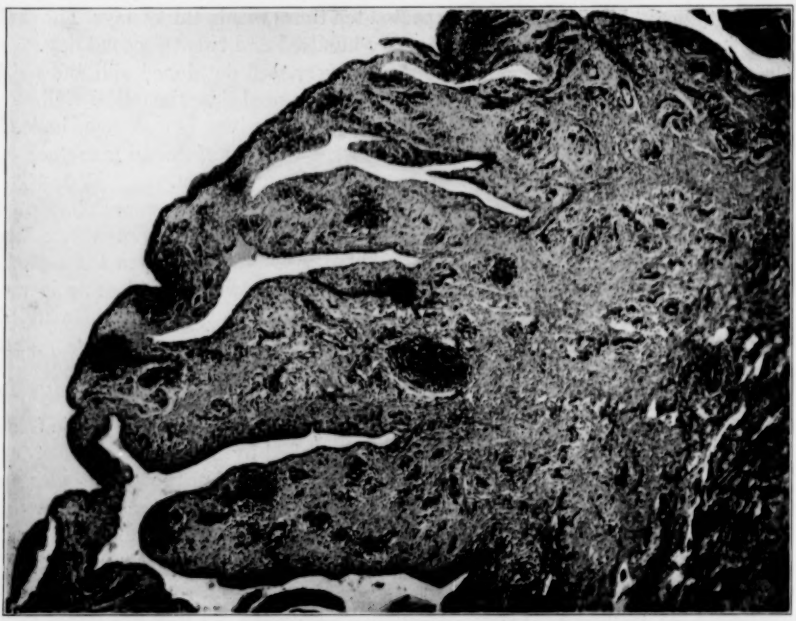

FIG. 13-A

Synovial villous hypertrophic arthritis in a man fifty-two years old. The adipose synovial membrane (× 22.5) is replaced by a fibro-areolar membrane with numerous villi. A fibrous layer is seen in the lower right portion; many nodules are visible.

FIG. 13-B

FIG. 13-C

Fig. 13-B: Detail of Fig. 13-A (× 175) shows large oval nodule, consisting mostly of mononuclear cells, without a trace of the basal substance.

Fig. 13-C: Detail of Fig. 13-A (× 175) shows (1) internal layer with deeply stained nuclei and desquamation of the edge; and (2) fibro-areolar layer, very lacunar, having vessels engorged with erythrocytes, fibrocytes, and large disseminated macrophages; there is finally an enormous nodule.

Fig. 13-D: Detail of Fig. 13-C (× 438) shows migrating cells; the majority participating in the formation of a nodule are plasmocytes.

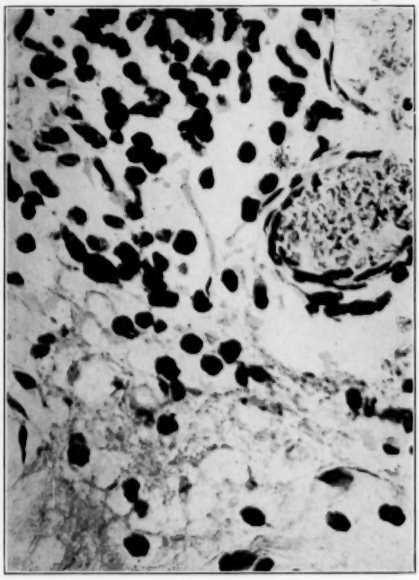

FIG. 13-D

A good explanation of the pathogenesis of chronic villous hypertrophic arthritis has not been made. The traditional means of research, consisting of microbiological and histological investigations, have not been productive. The studies of Klinge and his school may, however, help in understanding the problem. Klinge considered rheumatism to be a disease of mesenchymal tissue. Its specific histological manifestations consist of two elements: the first is degenerative,—the fibrinoid transformation of the basal substance of the connective tissue, which becomes waxy, strongly refractive, and acellular; the intrafascicular tissue is oedematous.

The second stage is proliferative,—namely, an increase in the number of mesenchymal cells, which invade the waxy substance, form little groups, and organize in nodules or granulomata. The blood cells (polymorphonuclear neutrophils, lymphocytes, and eosinophils) are variable in number. Plasmocytes are frequently present.

This conception of Klinge was based on numerous autopsies and also on experimental

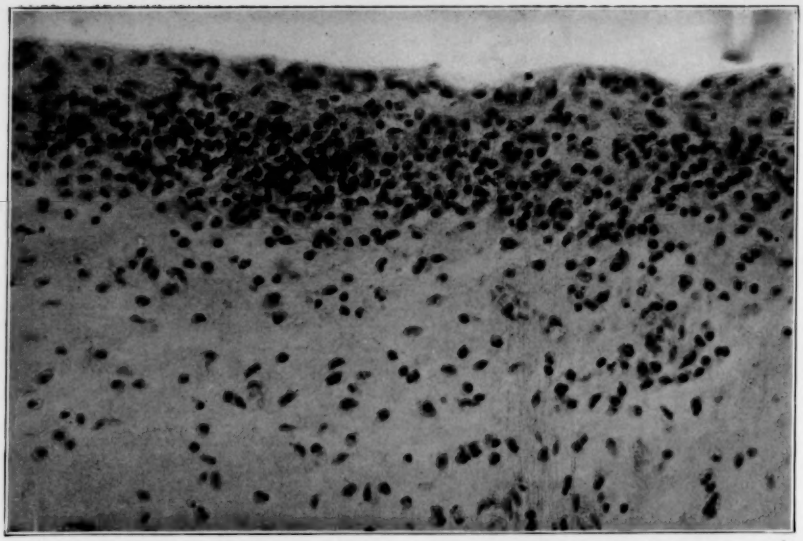

FIG. 14-A

Two cubic centimeters of horse serum was injected into each flank, and, twenty-eight days later, four injections of 0.25 cubic centimeter each, into the joint. The animals were sacrificed thirty-eight days after the last injection. Photomicrograph (× 250) shows the intima to be hypertrophied. The external layer is fibro-areolar. At the border between the two zones there is strong infiltration with plasmocytes and polymorphonuclear neutrophils.

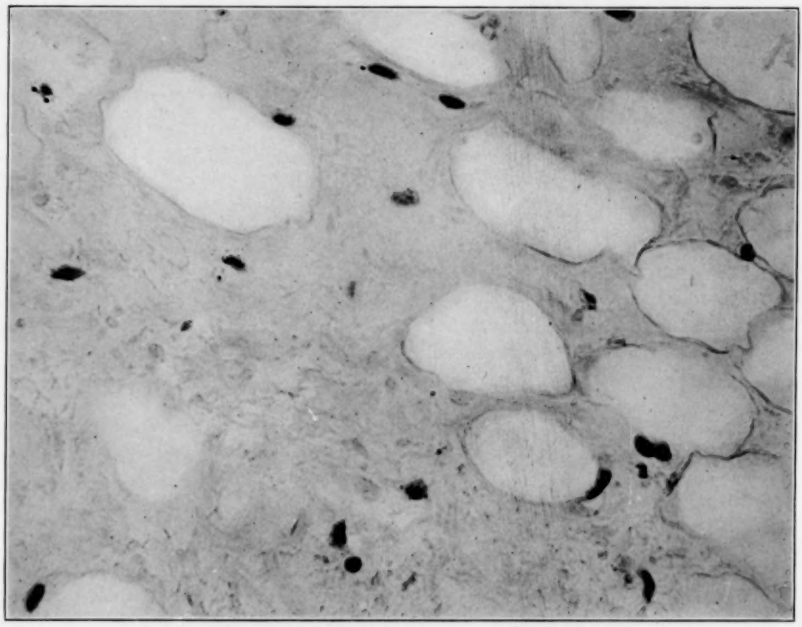

FIG. 14-B

Same preparation (× 500) shows waxy degeneration of fibrous tissue, swelling and homogeneization of the poorly stained fibrils, and a few cells. These areas contrast with the nodular aspect represented in Fig. 14-C.

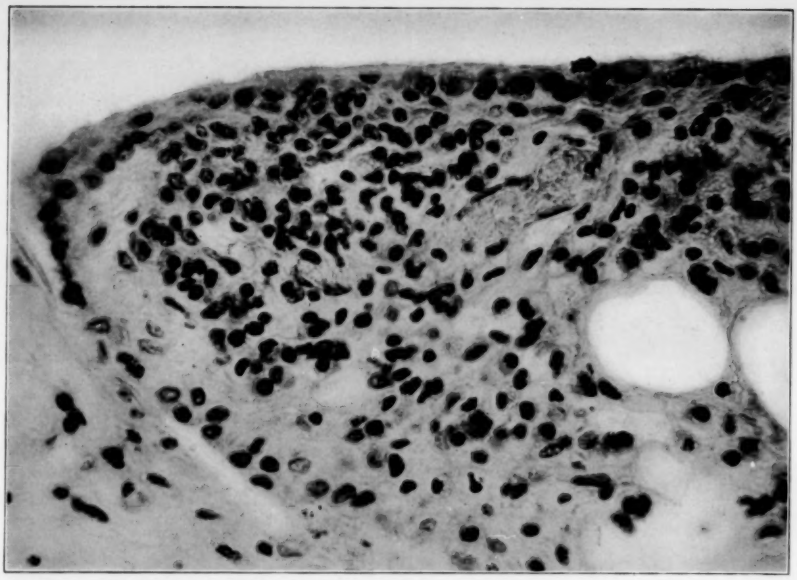

FIG. 14-C

Same preparation (× 500). A true nodule of inflammatory cells.

studies. Animals were sensitized by albumins, such as horse serum, or by bacteria like the Streptococcus or Pneumococcus. By the administration of the same antigen into the knee of the animal, anatomicopathological lesions are produced which are comparable to those observed in autopsy studies of rheumatic patients,—namely, dissolution and waxy necrosis of connective tissue, multiplication of fibrocytes, and formation of nodules.

On the basis of these findings, Klinge formulated the hypergia theory of rheumatism, consisting of application of tissue anaphylaxis to joints (phenomenon of Arthus). The rheumatic patient is a sensitized individual, hypergic to a bacterial or other toxin, derived either directly from without or from an internal focus. Under the effect of the same antigen or by action of a mechanical or climatic nature, such as cold, an allergic reaction of the mesenchymal tissues of the individual may develop.

We considered that it would be of interest to verify the theory of Klinge, because the German investigator believed that, in rheumatism, the synovial changes are primary, and the osseous and cartilaginous changes are secondary. Villous hypertrophic arthritis is an excellent example of synovial rheumatism.

Observations in Man

In this study nine synovectomies were performed for chronic villous hypertrophic arthritis (Figs. 13-A to 13-D).

We have nothing to add to the histological description of the American authorities, but a short résumé follows. Two aspects were considered.

At first, there was an intense cellular infiltration, involving plasmocytes, polymorphonuclear neutrophils, and mononuclears. The normal synovial membrane, as would be expected, showed only a limited number of plasmocytes and no leukocytic infiltration. Thus the free cells must either have become differentiated locally or have been brought in through the blood stream. The cellular infiltration also involved a large number of cells of indefinite origin, which may be compared with lymphocytes or small histiocytes.

Various abnormal elements were either disseminated in the subintimal region or

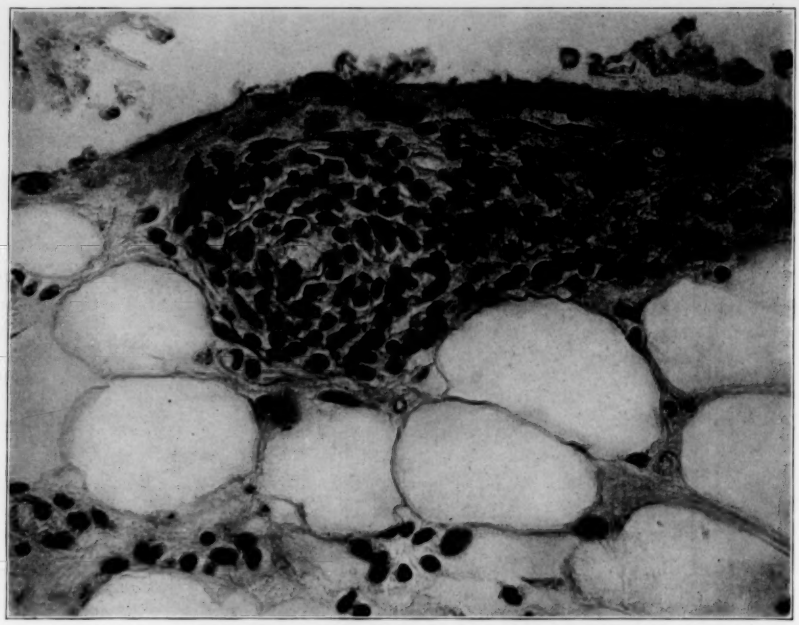

FIG. 15

Two cubic centimeters of horse serum was injected into each flank, and, beginning twenty-eight days later, four injections of 0.25 cubic centimeter each, into the knee, over a period of sixteen days. The animals were sacrificed 172 days after the last injection.

Six months after the occurrence of the phenomenon of Arthus, the nodules, consisting of plasmocytes and histiocytes, are still present in the intima (× 500).

grouped as a nodule. The most salient characteristic of the histological picture—namely, the cellular rosette either around or outside a blood vessel—was also present. Around the nodule a melting of the intercellular stroma was observed,—lacunar appearance of the basal substance with disappearance of the fibrils.

In the second stage, there was a hypertrophy of the synovial membrane in all its thickness, with transformation of the fat into fibrous tissue, activity of the entire villous zone, multiplication and sclerosis of the vessels, and finally oedema, probably associated with hydrarthrosis.

Observations in the Animal

In this study, rabbits were sensitized by injecting 2 cubic centimeters of horse serum into each flank. After an interval of one month, injections of 0.25 cubic centimeter of horse serum were made into the right knee of the animal; this procedure was repeated three or four times within ten or twelve days. The animals were sacrificed between the fourteenth and the one hundred and seventy-second day after the last injection.

Our findings were as follows: The intima was multistratified. Nuclei of the fibrocytic type were more numerous than are normally seen. The striking features were their swollen appearance, irregular outline, and poorly defined chromatic contents. The amorphous basal substance was thickened, poorly stained, and sometimes sent out free prolongations toward the articular cavity. An increased number of plasmocytes and polymorphonuclear neutrophils were found in the intima (Fig. 14-A).

The external layer had lost its adipose character. A few empty vesicles could be found, but they were small in size and depressed. The basal substance sometimes represented a finely reticulated tissue. The collagenous fibrils appeared swollen, homogenized, and only

slightly stained; in some areas of the preparation a few degenerated cells had accumulated (Fig. 14-B). These areas alternated with others which had a nodular appearance and were rich in irregular fibrocytes, histiocytes, plasmocytes, and polymorphonuclear neutrophils (Fig. 14-C). The vessels were surrounded with rosettes of round histiocytes, plasmocytes, rare mononuclears, and pyknotic nuclei.

This histological appearance reached its maximum definition toward the second month. If afterward the signs of tissue activity decreased, they still had persisted for a long time, because six months after the last injection traces were still present (Fig. 15). In these experiments, the left knee, which was not injected, was always examined and found to be normal (Fig. 2).

We also carried out the following control experiments:

1. Preparatory injections were made into the flanks without secondary injections into the knee.

2. Horse serum was injected into the joint of an animal without preliminary preparatory injections. The phenomenon of Arthus was never obtained in either of these experiments.

Conclusions

The histological picture of chronic villous arthritis is so well reproduced in experimental allergic arthritis that we are inclined to admit the identity of the mechanism. It is a reaction comparable to the phenomenon of Arthus, but obtained in a joint. These characteristics are:

1. Waxy transformation of some areas of the basal substance.

2. Important infiltration of the two layers of the synovial membrane by cells which are usually infrequent,—plasmocytes, polymorphonuclear neutrophils, and monocytes. These elements are either diffuse or well grouped and, when associated with fibrocytes, resemble the nodule of Klinge.

3. Signs of connective-tissue activity, including formation of villi, desquamation, cellular density of the intima, replacement of adipose tissue by fibrous tissue, and multiplication of vessels.

COMPARISON OF VARIOUS REACTIONS OF THE SYNOVIAL MEMBRANE

The changes observed in man are comparable with the reactions produced in animals. Three groups of facts should be considered.

By *synovial activity* we mean:

Increase in number and importance of folds and villi.

Irregularity of the free border and desquamation; the cells and basal substance "fall" into the joint cavity.

Multistratification of the intima.

Generalized proliferation of connective-tissue cells.

Swollen appearance of cells.

Hypervascularization.

By *fibrosis* we mean:

Fibrillation of the basal substance of the intima.

Disappearance of the adipose vesicles of the external layer and appearance of collagen bands.

Sclerosis of the walls of the vessels.

By *infiltration* we mean:

Multiplication of free cells, which normally are rare.

Appearance of new circulating cells.

With these definitions in mind, we are able to present a brief picture of the principal pathological changes observed in meniscal tears, effusions of blood, and synovial arthritis.

1. *Meniscal Tears*

(a) Synovial activity is marked at the onset; it subsides after six months.

(b) Fibrosis is the predominant element.

(c) Infiltration is usually absent; in certain very old or complicated cases it may be present, but in a discrete form.

The evolution is continuous and progressive.

2. *Effusions of Blood*

(a) Synovial activity is immediate, intense, and is limited to the intima.

(b) There is no fibrosis.

(c) The infiltration of the intima is acute: polymorphonuclears, especially mononuclears, and pigment cells.

The evolution is of short duration, and the synovial membrane becomes normal.

3. *Synovial Arthritis*

(a) Synovial activity is intense and generalized.

(b) Fibrosis is a secondary element, showing only waxy degeneration of connective tissue.

(c) The infiltration is either diffuse or in the form of nodules, with predominance of plasmocytes, then monocytes, and finally polymorphonuclear neutrophils.

The evolution is of long duration and is probably under the influence of further allergic responses.

CONCLUSIONS

This study permits us to define the cellular behavior of the synovial membrane to various irritants. In meniscal tears it is of mechanical nature, in hemarthroses it is of chemical nature (endogenous proteins), and in villous arthritis it is of an allergic nature (phenomenon of Arthus). The histological picture of each appears so different and so characteristic that it has a certain value in pathogenic research of a chronic affliction of the knee. We believe that it will be possible in the future to establish with precision, through a biopsy of the infrapatellar fat pad, the factor responsible for the origin of a morbid process.

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ETIOLOGY OF CONGENITAL DISLOCATION OF THE HIP *

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Hey Groves has well expressed the present-day concept of congenital dislocation of the hip as "a deformity which is mysterious in its origin, insidious in its course and relentless in its final crippling results". Numerous well-known theories for the development of this condition have been advanced. Extensive anatomical studies of normal foetal skeletons, and investigations of the pathological anatomy of foetal and postnatal material demonstrating true dislocations of the hip, have been reported. Genetic studies of the problem have indicated familial tendencies, with even a strong suggestion of a dominant Mendelian trait. Anthropological studies and knowledge of comparative anatomy have been utilized.

In general, two main theories for the etiology of congenital dislocation of the hip have predominated for many years. Throughout the literature, the main contentions for the various theories are based upon two assumptions,—one that the lesion is the result of a primary germinal fault; the other, that it is due to a defect of development of environmental origin. Recent experimental embryological work tends to show that many lesions, considered the result of a germinal defect, can be produced by environmental changes.

Although exponents of the mechanical theory can present convincing anatomical evidence to support their claim, few authorities accept this theory. The cumulative evidence of sex characteristics, hereditary factors, and geographical and racial incidence, the increasing recognition of an associated hip dysplasia on the so-called normal side, and the frequent occurrence of associated deformities have led to the more popular hypothesis of a primary developmental fault.

The most commonly accepted theory of developmental abnormality is a primary failure of proper formation of the acetabulum, particularly a germinal failure of development of the posterior superior buttress of the ilium. Murk Jansen, Bruce, Morrison, Hey Groves, Fairbank, and many others, including the present-day followers of the concept of primary acetabular dysplasia as emphasized by Faber and Hart, have believed that the flat socket is the primary developmental fault.

It is difficult to see how an observer, unless influenced by the weight of pre-existing statements and concepts, can authoritatively state a hypothesis as an accepted fact. The author denies dogmatically, for example, that there is scientific evidence of a primary genetic developmental fault of the posterior superior portion of the acetabulum. He does not refute the existence of such a lesion, but contends that no satisfactory evidence has been submitted that this lesion is the primary developmental fault. Similarly, several other authors have stated that, in the mechanism of development of congenital dislocation of the hip, although the acetabulum is defective, the head is within the socket with the hip in the typical intra-uterine position of flexion. On extension of the lower extremity after birth, dislocation may occur suddenly, or gradual displacement may result. With what proof is this statement of the time occurrence for congenital dislocation of the hip made?

There is on record, it is true, evidence of congenital dislocation in a five-month foetus. The teratological dislocation is undoubtedly prenatal in origin, and another type, to be discussed, also occurred prenatally. Rather should one say that the time of occurrence of congenital dislocation of the hip is not known, because of inadequate investigation in early life. Certainly Putti, stressing the features of early diagnosis by his triad of criteria, has demonstrated the possibility of recognizing preluxation of the hip at a much earlier age, by a process of education of the public and the doctor to look early for this abnormality.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 30, 1947.

FIG. 1

Child with abduction and flexion of right lower extremity and hyperextension of the tibia on the femur, associated with dislocation of the left hip, probably the result of the dangerous position of adduction in production of pathological dislocation. A roentgenogram of the mother's pelvis, one week before delivery, showed this same deformity *in utero*.

It is time for us to investigate the etiology of dislocation of the hip, free from prejudice, assembling the facts without bias. Conjecture should not be presented as fact.

MECHANICAL FACTORS

Mechanical factors producing dislocation of the hip have been recognized in the postnatal period. The position of flexion and adduction has been demonstrated in a number of clinics, including our own, as a dangerous position in hip-joint infection, leading to pathological dislocation. Certain isolated cases of congenital dislocation of the hip have been reported, which have a similar mechanical malposition, known to be a potential cause of dislocation of the hip in postnatal life. Tubby stated that Tridon had reported 121 cases of congenital dislocation of the knee, in twenty of which congenital dislocation of the hip occurred due to intra-uterine mechanical causes.

Through the courtesy of the Ford Hospital, the author has had the opportunity to see such a case of congenital dislocation of the knee, associated with abduction of the hip on the same side (Fig. 1). The opposite hip was adducted and dislocated. The foetal movements were said to be unusual, being felt in only one place above the left iliac crest. Roentgenograms of the mother, taken a week before delivery, clearly demonstrated the fixed deformity of the limbs *in utero*. Such an isolated case is, however, not a substantiation of the mechanical theory for dislocation of the hip except in unusual circumstances.

The mechanical concept of Le Damany and Dega seems plausible, but does not explain adequately the environmental, genetic, and racial features.

There are many factors opposed to the concept of a primary developmental defect of the acetabulum as the cause for dislocation of the hip. Numerous unsubstantiated explanations for this fault have been offered, such as early arrest of the Y cartilage and, more recently, a primary developmental failure of the posterior superior buttress of the acetabulum.

An intensive review of the etiology, in light of recent methods of embryological experimentation, is necessary. The information available at the present time is inadequate, but may show the possibilities for future study.

GENETIC STUDY

The approach to the problem of inheritance factors in congenital dislocation of the hip is very difficult. Patten has stated that the basic problem of the interplay of heredity and environment, although "both are involved in the causation of anomalous development", makes generalizations unsure as to their relative importance. Warkany and his associates found that feeding defective diets to normal breeding rats produced offspring with skeletal defects. Such findings, which hitherto had always been regarded as the result of a primary intrinsic fault, show the importance of extrinsic or environmental factors that may simulate a hereditary intrinsic fault. Patten stated that Stockard had produced experimental evidence "that different disturbances applied at the same phase of development would tend to produce the same defects, whereas the same disturbing factor applied at different phases of development produced different defects".

Hart, in an excellent paper on primary genetic dysplasia of the hip, quoted from Faber's work and his own to show that there are latent carriers of the gene for hip dysplasia. A true genetic history cannot be gained from a study limited to hip dislocation. Hart stated that hip dysplasia is due to a dominant gene. An incidence of about 20 per cent. of genetic occurrence in families has been reported by many authors. According to Hart, Faber demonstrated that dysplasia of the hip joint was three times as frequent as was classical dislocation. Therefore, a search for dysplasia of the hip shows a much higher incidence, as indicated by di Prampero's studies.

Patten has pointed out that enough data for genetic studies in man have not yet been accumulated to be definitely informative, that specific mating is not feasible, and that the heterozygous human germ plasm makes definite conclusions as to the importance of intrinsic and extrinsic factors most difficult.

PRINCIPLES OF DEVELOPMENT

We are indebted to Weiss for the following observations: Experimental embryology has added definitely to the knowledge of embryonic development. It seems to be established that there is, in general, almost a predestined mosaic pattern for development which, if carried out in a normal environment, will result in a normal development peculiar for the species. Each species, as well as each system of the species, has its own peculiar growth pattern. This growth pattern, inherently designed by intrinsic factors, is dependent, however, upon the environmental conditions, the *extrinsic factors*, under which it proceeds. Temperature, nutrition, and other environmental factors may accelerate or delay the normal growth rate. The predisposition for normal growth is the growth potential which may be interfered with by factors indispensable for its realization; these so-called "growth circumstantials", however, are not responsible for the characteristics of growth. The growth rate may be normal or abnormal. Embryonic growth of a part advances unevenly. Each system has its own time period, influenced and controlled to some extent by the body as a whole. Interference with growth of a part will produce far more abnormality during a phase of rapid growth than during a quiet phase. It has been shown that abnormalities in development do not depend upon the nature of the exciting factor so much as upon the time period of the disturbance of normal growth.

Perfect timing for the development of the constituent parts is essential. This is well demonstrated elsewhere embryologically in the failure of proper timing in the development of the heart valves, producing congenital heart lesions, and similarly in the time orderliness of the development of the eye. Patten has discussed the development of rachischisis of the spine from faulty timing in growth.

Parts of a joint can develop typically, however, even though they are not in continuity. Experiments in limb-bud transplantation have demonstrated that a typical socket is developed by the shoulder girdle when no humerus is present; and, similarly, that a typical head of the humerus has developed in the absence of a shoulder socket. Nevertheless, the continued embryonic growth of this intrinsically designed head or socket would alter without the environmental factors present to guide its intrinsic design. It is important to remember the fourth dimension, time, in this dynamic growth,—not what has happened, but what will occur as a result of environmental change.

Murray made the following statement: "Summarising, it may be said that the gross form of those kinds of elements which have been mentioned (mainly parts of the limb skeleton) is developed by self-differentiation, that is, under the direction of factors intrinsic in each developing element. These factors are not, however, sufficient for the production of a functional skeleton. In the early stages, when the development of gross form is proceeding, it is doubtless essential that extrinsic forces such as the growth pressure of other elements, etc. shall not deviate far from the normal conditions; it would be absurd to suggest that the intrinsic factors could produce a normal skeleton however unfavourable the extrinsic factors might be. In early stages the intrinsic factors are determinative, the extrinsic factors only important in providing conditions in which the intrinsic factors can act. In later stages, when the gross skeletal model is being refined and perfected, the importance of extrinsic factors increases. It is doubtless the correlation inevitably following upon development and early function in close contact that causes the two components of a joint to be so perfectly adapted to one another, and evidence has been presented which indicates that various grooves, prominences, etc., of the late embryonic skeleton are probably produced in reaction to extrinsic and presumably mechanical factors."

Hamburger and Waugh studied nerveless or poorly innervated limb buds and concluded that innervation played a minor role in the development of joint formation. Normally developed skeletal design often occurred in these transplants, in spite of isolation from the body and lack of innervation. Continued development of these abnormally placed and poorly innervated limbs is not recorded, but doubtless would be most inadequate. Hamburger and Waugh concluded that although "the primary development of the limb skeleton is thus shown to be self-differentiation to a high degree, extrinsic factors become of increasing importance in later phases of bone development". These studies all demonstrate the mosaic pattern for development; the growth potentiality is initially of great importance, but extrinsic factors may later alter the intrinsic design. Hamburger and Waugh quoted Harrison as warning against "the indiscriminate acceptance of the concept that differentiation proceeds universally from an undetermined state to one of rigid mosaic development".

It is important to recognize that the mosaic pattern may be interrupted or altered. The prospective potency—that is, the full range of developmental performance of which a given part of the germ is capable under any conceivable circumstances—equals its prospective fate, the lineage of each part of the egg through its cell descendants into a definite portion of the adult. One must have the concept of timing,—the dynamic concept of a changing structure. The tempo of operation is an important characteristic which each cell has inherited from the egg. Perhaps here the chief influence of heredity, environment, and geographic and racial characteristics is felt. An inherited alteration in the proper timing of growth of the hip system, or environmental delay or overstimulation, might well result in faulty development. To recognize the potentialities of normal or abnormal growth, the concept of the necessity for perfect timing during the various phases of growth of the hip joint must be understood.

Rotation of the Limb Bud

The evolution of posture of the pelvic limbs is characteristic for the human species.

This alteration of position is a well-recognized embryological fact of great importance clinically and anatomically. It has been shown by a number of observers, particularly Bardeen and Lewis, that the limb buds in the human embryo undergo a rotation phenomenon. Bailey and Miller stated that the lower limb bud appears at the end of the third week as a small rounded protuberance on the lateral body wall, opposite the sacral flexure. During the fourth week, elongation occurs and the transverse constriction, separating the proximal from the distal portion, develops. During the sixth week, the limb bud is marked off by a bend for the knee.

As the limb buds first elongate, their long axes lie nearly parallel with the long axis of the body. Later they are directed ventrally, nearly at right angles to the body axis. The tibial margins are turned toward the head. To acquire positions relative to the body as found in postnatal life, the extremities must undergo further changes. These consist of torsion around their bony axes and rotation through an angle of 90 degrees. The right lower extremity twists to the left. At the same time both extremities swing backward through an angle of 90 degrees, so that they lie parallel with the long axis of the body.

It is clear from the illustrations of selected embryos (from 8 millimeters to 58 millimeters) that the alteration of position of the limb buds starts prior to the separation of the component parts of the hip joint. Even the 15-millimeter embryo shows lessened abduction of the limb bud. Doubtless this alteration is influenced by growth of the embryo in length. It seems obvious that this postural change of the limb bud prior to motion in the hip joint may be a definite factor in the production of the inclination of the neck of the femur, characteristic of the human species. Most of the postural change of the limb buds develops, however, after the separation of the head of the femur from the acetabulum, which appears usually after the 30-millimeter stage of the foetus.

Thus the hip joint is peculiar in its development. Originating in a lateral abducted position to the pelvis and acetabular anlage, the head of the femur and the shaft must adduct to a position parallel with the long axis of the trunk, practically 90 degrees, and must rotate internally approximately 90 degrees at the hip joint to allow the patella and leg to face forward. Much of this rotation occurs during the third month, but is not complete even after birth. Some degree of retention of the foetal position of external rotation is commonly seen months after birth, even continuing at times until adolescence.

Not only are adaptive changes in the acetabulum and the upper end of the femur necessitated by this rotation phenomenon, but there is development of the oblique position of the acetabulum to the sagittal plane. An increase in growth of the posterior portion of the pelvis in proportion to the extent of growth of the pubic portion is a well-recognized anatomical fact. Thus the position of the acetabulum is developed with a forward and a downward inclination. Steindler gives a statistical report of 40 degrees of forward inclination and 60 degrees of downward inclination. In a recent study from our clinic by Donovan and Campbell on the adult pelvis, the angle of forward inclination was 30 degrees and the angle of downward inclination was 60 degrees.

Dega, in a review of 100 foetal skeletons, showed the angle of forward inclination of the acetabulum to be 29.5 degrees. The downward inclination in relation to the transverse plane was 62.8 degrees. Dega showed that the downward inclination increased gradually, paralleling the increase in anteversion of the neck of the femur. The decrease in the forward inclination of the pelvis, however, did not begin until the eighth or ninth foetal month.

Le Damany pointed out that the human foetus has undergone three deformities at the time of birth which are not found in animals: First, he referred to the pelvis deformed by tilting of the iliac bone on the sacrum with enlargement of the pelvisacral angle; second, to obliquity of the acetabulum; and, third, to anteversion of the head and neck of the femur, associated with torsion of the femur. He argued that, if the sum of the obliquity of the acetabulum and the anteversion of the neck is greater than 60 degrees, dislocation occurs.

The author [1,2] has pointed out that the characteristic posture of the limbs in arthrogryposis multiplex congenita closely approximates the early foetal position of the limb buds. We attribute this to failure of rotation of the limb buds, due to the absence of muscle function in the extremities, which is characteristic of the syndrome. This emphasizes the importance of the foetal muscles in the production of torsion and anteversion, as, with extensive muscle involvement, neither torsion nor anteversion is evident if the limbs are in the characteristic posture. In the instances of this syndrome associated with dislocation of the hip, the response to abnormal position of the constituent parts of the hip joint is beautifully illustrated by the case of R.L.M.[2]. Operative inspection demonstrated that the head, having laid above the acetabulum anteriorly, had produced a marked notch in the ilium, which was undoubtedly the result of diminished growth from pressure. The ilium above the displaced head of the femur grew forward normally. The head was then pointing directly into the pelvis and into the iliacus.

Lack of rotation of the limb bud, the retention of the foetal position of the limb, and the position of abduction in these cases may have levered the head forward and left it displaced in a subspinous position. The malposition of the head produced a failure of development of the cartilaginous anlage for that portion of the anterior margin of the ilium pressed upon by the head of the femur. This demonstrates environmental restraint of growth. McCarroll and Crego have reported a similar defect in the anterior margin of the ilium in their cases of anterior dislocation of the hip.

This is an adaptive environmental change, not a primary developmental fault. It is, however, analogous to the maldevelopment of the posterior superior surface of the acetabulum, regarded by many as the resultant of a primary developmental fault.

Dega, in his careful study of the skeletal anatomy of 200 foetal hips, noted marked similarity in the measurements of the head and acetabulum. This, he felt, demonstrated the reciprocal relationship between the two structures. He pointed out, however, that perfect adaptation of the component parts was present only in one position,—the intrauterine position of flexion. He was of the opinion that dislocation of the hip was definitely a consequence of a bad adaptation of the human species to an upright posture. Regardless of this opinion, the anatomical fact remains that the shape of the socket and the head were congruous in their development when normal, denoting that, in the absence of an environmental fault, such a development is the mosaic pattern for the hip joint. Perfect formation of the joint for this reciprocal development requires perfect adaptation and timing for the altered positions of the components of the hip joint during rotation of the limb bud.

EMBRYOLOGICAL SECTIONS

Through the courtesy of the Department of Anatomy, we have selected a few transverse sections of the developing hip joints of embryos, varying from 8 to 58 millimeters. These sections illustrate the findings which were so well presented by Luther Strayer. The author has utilized Strayer's work freely in interpreting these sections.

In a transverse section through the lower limb buds in an 8.5-millimeter embryo (Fig. 2), the neural tube was at the top. The limb bud was in the finlike position, protruding laterally, and consisted of a mass of undifferentiated mesenchyme. From this period on, the limb bud develops as an entity, only the nerves and vessels growing in from the trunk. There is no definite evidence of the trunk sending other constituents to the limb bud.

As the embryo elongates to 14.8 millimeters, the limb bud develops further, descending ventrally and less laterally (Fig. 3-A). The constriction and bend for the knee become apparent. The mesenchyme shapes itself into the outlines of the blastemal innominate, and the dumbbell-shaped femur is outlined (Fig. 3-B). A hint as to the future site of the hip joint may be observed at the dense accumulation of mesenchyme. The abducted position of the thigh and the external rotation of the limb bud may be noted at this stage. Nerve tissue is present in the popliteal space.

At 25 millimeters, there is further differentiation of the hip joints. The innominate structures are clearly outlined; there is a clearly differentiated acetabular development and a rounded femoral head. Undifferentiated mesenchymal tissue is still present between the outlines of the head and acetabulum, connecting the two structures, which are not yet separated. The capsular structures are forming and there is early evidence of the development of the glenoidal labrum. Further rotation of the limb bud is obvious.

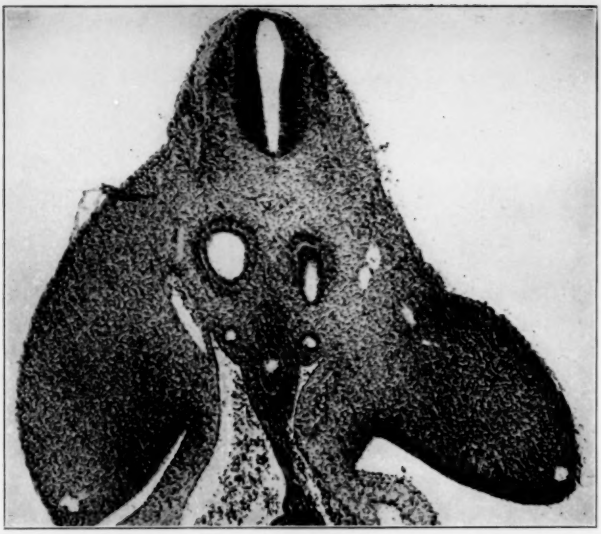

FIG. 2

Transverse section through lower limb buds in an 8.5-millimeter embryo shows neural tube at the top.

A section at 28 millimeters shows more clearly the cartilaginous nature of the innominate bone and the femur, and the retention of numerous cells about the head of the femur (Fig. 4). Mesenchymal tissue, still undifferentiated, fills the space between the acetabulum and the head of the femur. An early appearance of the glenoidal labrum is suggested in the increased density of the mesenchymal tissue above the head of the femur. The two components of the sciatic nerve are present, just medial to the tip of the trochanter. The external rotator muscles are well defined. The amount of abduction of the hip has diminished to about 60 degrees. Inasmuch as there is no separation of the head of the femur from the acetabulum, this must be the method for developing the angle of inclination of the neck of the femur.

As seen in the 33-millimeter embryo, the formation of the joint space is completely differentiated throughout, but clearly separate in the upper third. The ligamentum teres makes its appearance at this time, and the glenoidal labrum has extensive prolongation over the head of the femur. The capsule has separated from the glenoidal labrum and is attached above it; the articular surface of the acetabulum is continuous with the articular margin of the glenoidal labrum. The differentiation of muscle structures and nerves is clearly seen. Photographs of the embryo show the continued rotation of the limb buds (Figs. 5-A and 5-B).

In a section of a 53-millimeter female, taken at the level of the greater trochanter (Fig. 6), the ligamentum teres, the transverse acetabular ligament, and the glenoidal labrum are shown. At this stage the ligamentum teres is attached to the head; the capsule is attached above the glenoidal labrum.

In a 58-millimeter male, there was marked lessening of the abduction, and the ligamentum teres and its vascularity could be seen. The importance of the glenoidal labrum as a "sucker" ligament was obvious in the deepening of the socket. Beginning ossification of the ilium was taking place.

Comment

These sections reveal the development of the limb bud, and particularly of all the elements of the hip joint from the undifferentiated mesenchymal tissue to a structure

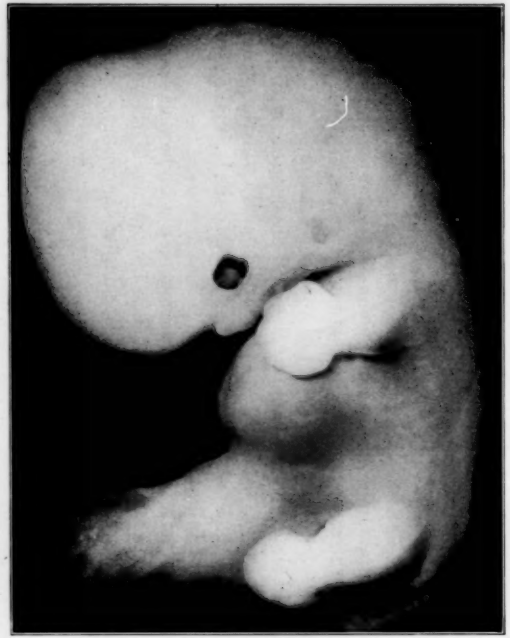

FIG. 3-A

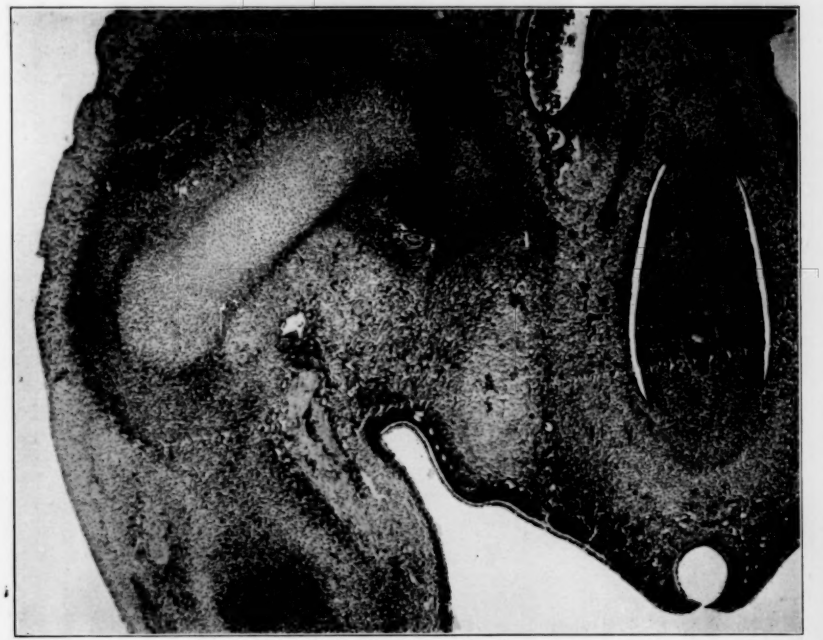

FIG. 3-B

Fig. 3-A: 14.8-millimeter embryo, demonstrating the alteration of position of the limb buds with the development of the knee bend and more central turning of the limb. The angle of inclination of the neck is probably formed by this bending, prior to separation of the head of the femur from the acetabulum.
Fig. 3-B: 14.8-millimeter embryo, after section. Outline of femur can be seen.

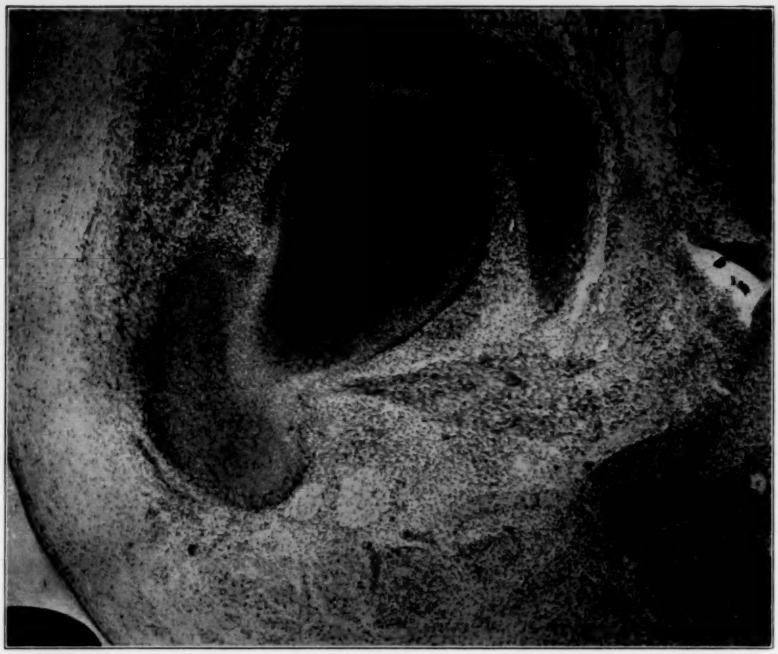

FIG. 4

Section of 28-millimeter embryo shows cartilaginous nature of innominate bone and femur.

that closely resembles the developed hip joint with all of its recognizable adult characteristics, in the short period of growth from an 8.5-millimeter embryo to a 53-millimeter female foetus. The hip-joint space was first noted in the 33-millimeter embryo in this series. Strayer pointed out that, in six embryos between 36 and 45 millimeters which he examined, development of the joint space was well under way. He said it had been suggested that factors of muscle innervation and function probably have some influence on the time of opening of the joint space. Early maturation of the neuromuscular mechanism might cause a joint to be opened early, while a slowly developing neuromuscular apparatus might allow the embryo to reach a greater length before this occurred. This constitutes a possible determining time factor which may alter the rigid mosaic of the intrinsic design.

One must be impressed by the orderly development of this undifferentiated mesenchymal mass into the predetermined structural design of the mature characteristics of the hip joint. The intrinsic mosaic pattern for development in a normal environment is illustrated (Fig. 7). Can there be an inherited failure of development of the posterior superior border of the acetabulum in such a developmental cycle, indicating that all of the elements of the hip joint are differentiated *in situ* from one mass of mesoderm? Such a concept seems incredible.

ENVIRONMENTAL THEORY

Hereditary factors and environmental factors, such as geography and nutrition, may well alter the normal rate of growth and interfere with chronological development by delay or stimulation of growth. Delay in innervation of the muscles or in rotation of the limb buds at a period of rapid growth may produce an alteration in the deepening of the socket and changes in the head and neck of the femur. The adaptive variations to the stimulus of pressure and abnormal positions of the constituent parts of the hip joint,

FIG. 5-A

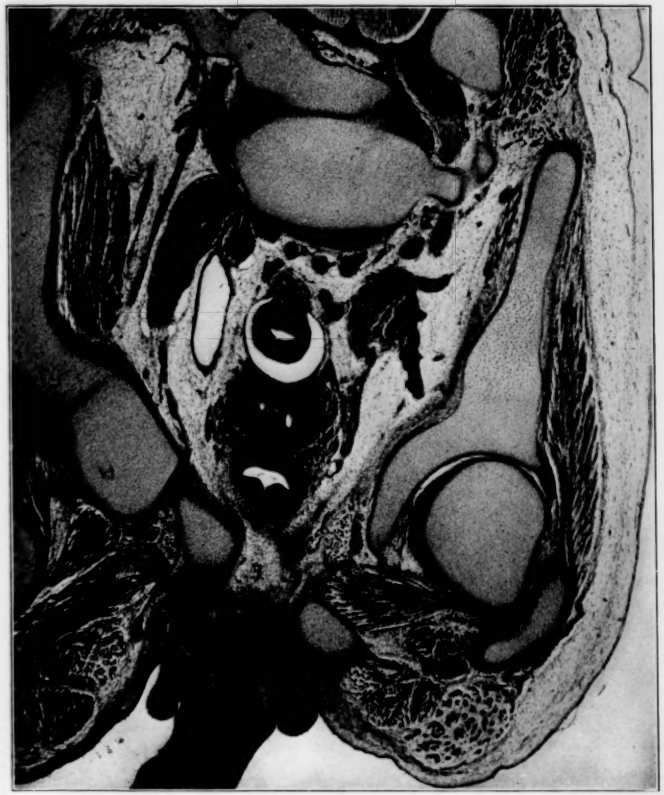

FIG. 5-B

Fig. 5-A: Photograph shows the continued rotation of the limb buds in a 33-millimeter embryo, with the patella still facing somewhat laterally.

Fig. 5-B: Section of 33-millimeter embryo, showing the continued rotation of the limb buds. The capsule is separated from the glenoidal labrum; the articular surface of the acetabulum is continuous with the articular margin of the glenoidal labrum. The differentiation of muscle structures and nerves is shown.

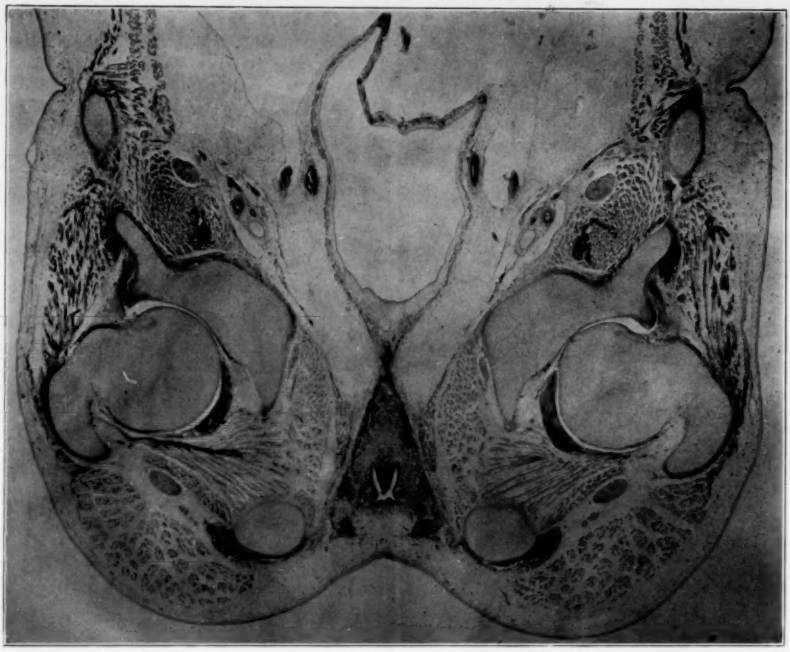

FIG. 6

Section of a 53-millimeter female embryo, taken at the level of the greater trochanter.

recognized by clinicians in the postnatal changes, can certainly occur with even more marked alterations in a shorter period of time in the early prenatal phase. Why do we accept the postnatal changes in congenital dislocation of the hip as adaptive to malposition, and yet fail to recognize the potentialities of environmental or adaptive changes *in utero?*

Can it be said in one breath, as Murk Jansen and numerous of his followers have reported, that the flat socket is primarily the developmental fault, and in the next breath that the changes in the femur are secondary adaptive changes? Is it not more reasonable to assume in a structure of component parts, such as the hip joint, conjugated from a single mass into its integral parts, that the fault lies not in a hereditary failure of one part, but in an interference in the orderly time development of reciprocal parts after the formation of the joint cavity? It seems more logical to anticipate changes from extrinsic factors in both the acetabular structures and the femur, on the basis of a secondary adaptive fault from an alteration in the normal timing of development. A delay in position, even of short duration, might well alter the normal dynamic rearrangement of the component parts, so that normal development is interfered with to the extent of reciprocal changes in the hip structures. These may well be manifested by a shallow socket, enlargement of the head to accommodate it, increased anteversion, and even subluxation. This would account logically for all of the recognized deformities noted in congenital dislocation of the hip.

The Glenoidal Labrum

It is, of course, an anatomical fact that the acetabulum and its margins are entirely cartilaginous at the time of birth. The depth of the true acetabulum is greatly increased during prenatal life by the fibrocartilaginous structure called variously the limbus, the cotyloid ligament, and the glenoidal labrum. This ligament aids in enveloping the head of

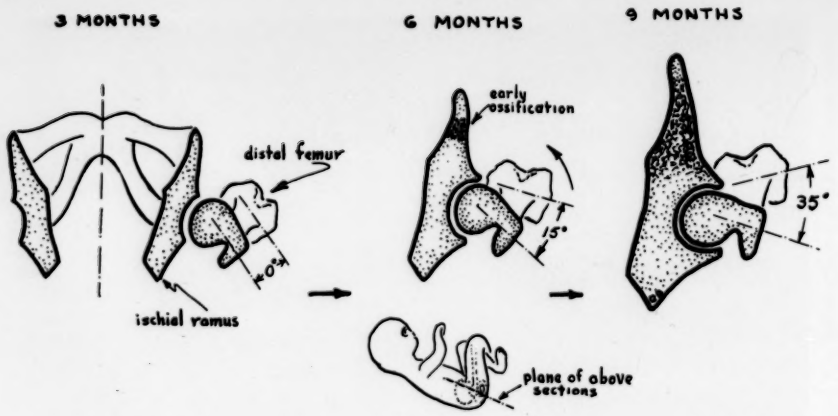

FIG. 7

Development of the normal hip joint. Graphic attempt to illustrate the reciprocal development of the head of the femur and the acetabulum, as the limb buds alter their lateral position to one of parallelism. The torsion of the femur, the change of position of the ilium, and the increasing anterior obliquity of the acetabulum produce an increasing anteversion of the diaphyseal junction from 0 degrees at three months to 35 degrees at birth. The acetabulum steadily deepens and the head, properly fitting the socket at all stages of rotation, is symmetrically developed for the socket.

the femur. Severin developed an excellent illustration from a roentgenogram, demonstrating the size and importance of the glenoidal labrum in the newborn, by painting with an opaque substance the dissected edge of the limbus. No one has mentioned any primary deficiency of the limbus, and yet it is an early embryonic development of obvious importance in increasing the depth of the socket and thereby maintaining stability of the femoral head within the socket.

Severin [27] also described how Faber demonstrated in normal hip joints, by opaque-media arthrograms taken after birth, that the cartilaginous acetabulum and limbus covered at least half of the femoral head. The normal head is spherical in shape.

In subluxation, a term which we believe to be synonymous with dysplasia of the hip, the limbus is displaced upward, covering less of the head but still remaining above the head, which is between the limbus and the socket. The head is displaced laterally, with apparent coxa valga, in Severin's illustrations. This malposition is the result of anteversion and not of coxa valga, as can readily be proved by roentgenograms taken with the lower extremity in internal rotation. In true dislocation, the limbus lies between the head and the acetabulum. Severin stated that the head glides past the glenoidal labrum which, because of its elasticity, returns to its position below the displaced head of the femur.

An important report was made by di Prampero, based on a roentgenographic study of 200 patients with unilateral dislocation, to determine the principal characteristics of the so-called healthy side. Subluxation or dysplasia of the hip was found in 108 cases, subnormal hips in 41, and normal hips in only 51 cases. Eighty per cent. of the so-called normal hips showed pathological changes. Di Prampero believed this parallelism of deformity demonstrated that the articular imperfection is not located in the hip, but in the pelvis as a whole and in the individual himself. With this observation the author is in full accord.

Various observers have demonstrated roentgenographic methods of determining abnormalities in the very young infant, leading to or suggesting the possibility of the development of so-called acetabular dysplasia or congenital dislocation of the hip. These measurements, namely, Wiber's lines, the acetabular index of Kleinberg, the Y line, and Shenton's line, all tend to demonstrate Putti's triad for so-called preluxation of the hip. This consists in:

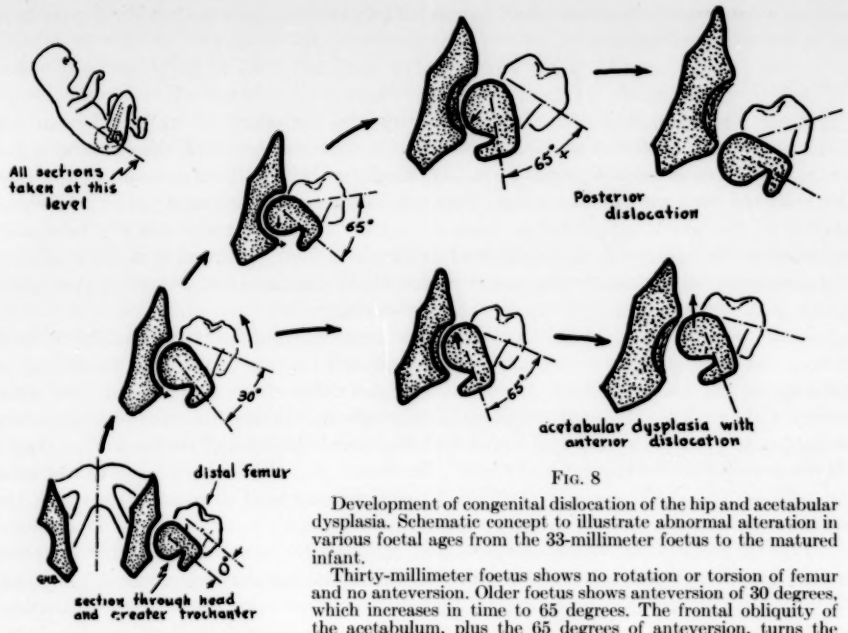

FIG. 8

Development of congenital dislocation of the hip and acetabular dysplasia. Schematic concept to illustrate abnormal alteration in various foetal ages from the 33-millimeter foetus to the matured infant.

Thirty-millimeter foetus shows no rotation or torsion of femur and no anteversion. Older foetus shows anteversion of 30 degrees, which increases in time to 65 degrees. The frontal obliquity of the acetabulum, plus the 65 degrees of anteversion, turns the head anteriorly away from the socket. The stimulus of contact and pressure, to produce normal deepening of the socket and the reciprocal shapes of the socket and the head of the femur, is lacking. The head and neck, pointing forward, may rest against the posterior cartilaginous border of the socket and produce hypoplasia. The head may then become spontaneously displaced posteriorly.

If, however, the delay in the proper timing of the rotation of the head into the socket is minimal or less prolonged as growth continues, anteversion with a malshaped head and a flat socket may develop without the demonstration of a true dislocation, but rather with changes from mild to severe acetabular dysplasia. These are adaptive changes to a loss of the normal chronological fit of the head and socket, during the process of adaptation to parallelism of the limbs.

1. An increased distance between the upper femoral epiphysis and the acetabular floor,—that is, lateral displacement;

2. Hypoplasia of the bony nucleus for the epiphysis of the head;

3. Increased angulation of the acetabular roof.

These changes are not evidence of a primary flat socket or of primary hip dysplasia. All can be produced by adaptive changes. The anteversion of the head and neck of the femur can be demonstrated by correction of the relationship through internal rotation and abduction only. How can one ignore the reciprocal changes in the head and neck in these young infants, or call them secondary changes, when they are as marked a part of the deformity as is the acetabular change? Convention and habit may be the chief reason. The author believes that both deformities are reciprocal faults, secondary to a developmental error, possibly both hereditary and environmental in character. They are not hereditary in the sense of a gene which fails to develop a part of the acetabulum, but rather a hereditary quality of interference of the timely development of the intrinsic mosaic pattern, producing environmental extrinsic faulty development which leads to the abnormality. This is entirely consistent with the known facts of embryological joint development. In what other joint formation has there been a failure of development from a primary developmental fault of part of a structure? One cannot compare the failure of approximation of separate components, such as is seen in rachischisis of the spine or cleft palate, with a structure originating as a single mesenchymal mass, differentiating origi-

nally as a continuous structure which separates into its conjugate parts after a growth of the foetus to 30 millimeters.

Anteversion

Some observers, including Fairbank, deny the frequency of anteversion in hip dysplasia and dislocations, possibly because of a faulty concept of where anteversion occurs. Anteversion occurs primarily in the diaphysis below the upper epiphyseal line. The head and neck may be in normal relation with the trochanters and yet anteverted in relation to the shaft; or, probably more accurately, torsion of the shaft is increased. Anteversion can occur with retroversion of the head. In fact, retroversion of the head may be a compensatory mechanism for anteversion. Most clinicians feel, however, that anteversion is a common accompaniment of hip dysplasias.

Murk Jansen stated: "In congenital dislocation of the hip, anteversion of the femoral neck. . . is a constant phenomenon". He attributed this to a primary flattening or widening of the socket. Tubby, Hibbs, Krida, and others have emphasized that anteversion of the neck is a frequent complication of congenital dislocation, usually a secondary phenomenon. Watkins stated that Lange had contended the head of the femur "originally left the acetabulum by the anterior route". He stated that the forward twist of the head and neck on the shaft was apparent in all cases of congenital dislocation in which the patient had walked.

The author has previously stressed that anteversion is not a secondary adaptive change, but is rather an integral reciprocal deformity, resulting and developing concurrently with the changes in the socket, the one dependent upon the other for the extrinsic or environmental factors necessary for the dynamic development of the hip joint. The roentgenographic evidence of an apparent coxa valga is proved faulty when roentgenograms are taken with the lower extremities in internal rotation. The angle of inclination will be found to approximate the normal, demonstrating that coxa valga itself rarely occurs; but anteversion rotates the head and neck outward, producing this false or apparent coxa valga.

Similarly, we have mentioned that Putti's triad is evidence primarily of anteversion and not of true displacement. Internal rotation associated with abduction will show a normal angle of inclination, and the epiphysis is properly replaced in its relation to the acetabulum.

CONCLUSIONS

From the facts presented, it would seem logical to conclude that the etiology of congenital dislocation of the hip is a developmental fault of the hip system produced by extrinsic factors—growth circumstances—with a combination of hereditary and environmental faults which alter the normal growth potential or the intrinsic mosaic pattern. Congenital dislocation and congenital dysplasia are developmental deformities produced by secondary adaptive changes. Inherited characteristics and environmental factors may alter the intrinsic mosaic pattern by a faulty timing in development. Patten states that "local overgrowth may be responsible for certain anomalies, just as local arrests may be responsible for others. . .".

Our concept of congenital dysplasia of the hip and congenital dislocation is that, through a developmental fault, the acetabulum has failed to deepen and the head and neck of the femur have become anteverted. The anteversion tends to turn the head forward, displacing the cartilaginous sphere laterally, so that the glenoidal labrum and acetabulum cover less of the head than usual. The poor adaptation of the head and acetabulum continues dynamically to require altered growth changes, altering the intrinsic mosaic pattern. These growth changes are manifested in subluxation or acetabular dysplasia by pushing upward of the glenoidal labrum, widening of the socket, and enlargement of the

head (Fig. 8). If the head escapes completely past the edge of the glenoidal labrum, a true dislocation results. The glenoidal labrum, unobstructed, returns by its elasticity to its proper position, lying between the head and the acetabulum. The head of the dislocated hip no longer has the stimulus for overgrowth seen in the subluxation, so that it remains small and round, although becoming flattened on the side if in contact with the ilium.

This mechanism is in complete accord with the pathological findings in early postnatal hip dysplasias, demonstrated by arthrograms and by operative findings. It is to be remembered that anteversion occurs below the trochanters and actually is associated with torsion of the femoral shaft.

It would seem a logical hypothesis that the rotation of the limb buds may be an important factor in the abnormal development. Presumably there must be an adaptive alteration in the change of position, from the origin of the hip joint in the first few weeks of embryonic life to the 90 degrees of rotation and adduction of the hip in the second four weeks of life. Interference with the orderly timing of this rotation—the embryo being held in a position overlong for even a short time—could produce a failure, mild or severe, in the intrinsic mosaic design. The altered environment could produce the adaptive features which are seen in all the structures of the hip joint, and not a primary change in the acetabulum alone.

These studies lead to the following hypothesis: Congenital dislocation and congenital dysplasia of the hip may be regarded as the result of faulty development, due to environmental factors extrinsic to the hip joint. An inherited fault in the timing of development may produce these extrinsic changes. The loss of the normal dynamic reciprocal relationship of the component parts of the hip joint during the stage of rotational adjustment of the limb buds may produce the secondary adaptive changes which lead to acetabular dysplasia or congenital dislocation. Heredity can play an important part in altering the growth and time factors. The known embryological development of the hip joint is certainly opposed to the theory of a primary inherited failure of development of a portion of the acetabulum.

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CONGENITAL DYSPLASIA OF THE HIP JOINT

Relationship between Congenital Subluxation and Congenital Dislocation *

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Since congenital subluxation of the hip as an entity has not been fully considered before this Academy, or included as such in the chapters on congenital dislocation of the hip in American textbooks, the author believes that the relationship between subluxation and dislocation deserves special attention. Leading European schools recognize this relationship. We will gain a more complete concept of the problems of congenital dysplasia of the hip joint with dislocation if we, too, accept and teach the pathogenesis of subluxation.

If, during embryonic or foetal life, a flat and shallow socket forms or a primary dysplasia of the acetabulum occurs because of genetic and biomechanical influences, either alone or in combination, five possibilities exist for subsequent growth of the hip joint. First, there may be complete displacement between the femoral head and the maldeveloped acetabulum with clinical, roentgenographic, and pathological findings of classical posterior dislocation or superior dislocation of the hip. Second, the displacement between the femoral head and the flat socket may be incomplete, but always with some contact of the articular surfaces of the head, socket, and limbus, and without capsular interposition. This condition, known as congenital subluxation, is also a distinct clinical, roentgenographic, and pathological entity. It is now an established fact that congenital subluxation of the hip, which was thought to be only a precursor of the classical dislocation, may remain throughout life as a permanent and eventually a disabling deformity. Third, there may be no displacement between the femoral head and the shallow dysplastic acetabulum. This condition also may be a definite clinical entity and remain as such throughout life (Fig. 1).

These three hip-joint entities, therefore, are identical in their etiology, but differ in their clinical and roentgenographic manifestations. There is also a fourth and rare entity, associated with extreme dysplasia, shortening of the shaft of the femur, and irreparable malformations of all structures of the hip joint. All four entities are definite clinical expressions of congenital dysplasia of the hip joint and have a common etiology.

Fifth, the dysplastic hip, with no treatment, may return to normal during either intra-uterine life or early infancy, as a result of the rare phenomenon of spontaneous recovery (Figs. 2-A and 2-B).

If it is true that congenital dysplasia of the hip is always bilateral during embryonic or early foetal life, then unilateral postnatal dysplasia of the hip, with or without displacement of the femoral head, must denote spontaneous healing of the opposite, apparently normal hip joint. If all dysplastic hips possessed the full capacity for spontaneous recovery, congenital subluxation and dislocation would never become serious problems. No one knows the potential capacity of the structures of the dysplastic hip to return, partially or completely, to normal. The growth capabilities of the tissues may be temporarily or permanently inhibited, with varying degrees of malformation. Whether the inherent capability for recovery is feeble or abundant, it is axiomatic that age is the most important factor in influencing the results of treatment of congenital dysplasia of the hip. A favorable mechanical and functional position, obtained by treatment during the period of infancy before weight-bearing, not only enhances the potential growth power of

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the maldeveloped hip joint, but also prevents secondary pathological changes. During this age period, dysplasia of the hip with subluxation is common; with dislocation, rare.

The purpose of this study is, first, to focus attention on congenital subluxation, which is frequently unrecognized as a distinct entity and often coexists with classical dislocation of the opposite hip; and, second, to establish the common etiology of the two conditions.

To prevent confusion, one must understand that all congenital dislocations and subluxations are not the result of primary dysplasia or maldevelopment of the acetabulum. Spina bifida with paralysis of an extremity, intra-uterine flexion-adduction of the hip in breech posture with the foot placed over the shoulder, intra-uterine chondro-osteodystrophy, and intra-uterine muscular dystrophies with degenerative fibrosis and contractures of muscles, as seen in myodystrophia foetalis or arthrogryposis multiplex congenita, may cause displacement of the femoral head from the acetabulum.

Congenital subluxation should not be confused with residual subluxation. In congenital subluxation, the hip has at no time been dislocated. Residual subluxation is a partial redisplacement of the femoral head, subsequent to closed or open reduction of a dislocation or to failure to obtain complete reduction. Residual subluxation of some degree occurs in the great majority of dislocated hips after reduction.

One is not justified in attempting to explain all congenital displacements of the hip on the basis of a single mechanism. There are several causes of congenital dislocation and subluxation before birth, just as there are several causes of hip-joint displacement after birth. In this paper, the discussion is limited to the displacement of the hip joint which is

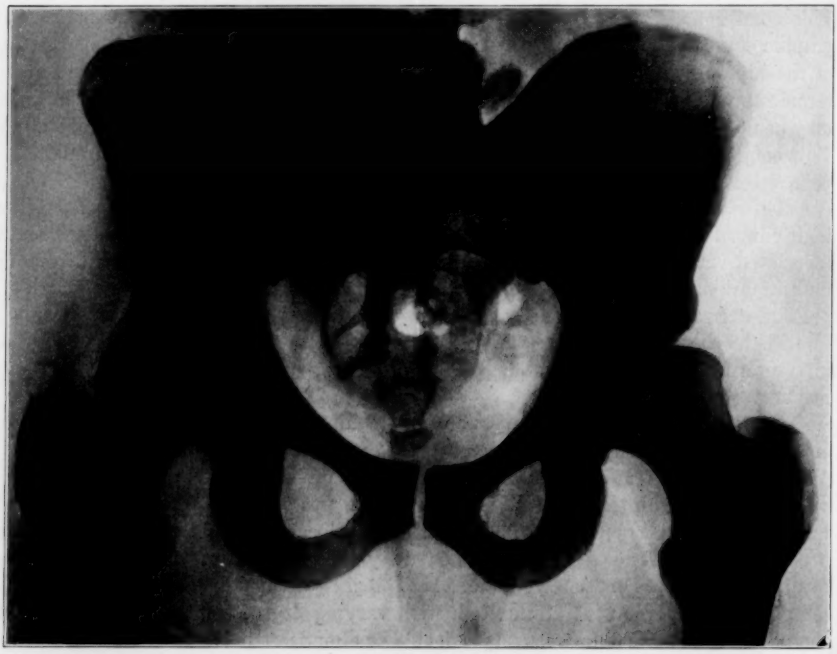

FIG. 1

Bilateral flat dysplastic socket with practically no upward displacement. Each femoral head is broadened in its transverse diameter and is irregular (coxa magna). The patient is now in early adult life and has no disability except fatigue in the hip and low back after strenuous exercise. Traumatic osteoarthritis will gradually develop because of the hip-joint incongruity. Osteochondritis dissecans has been observed as one of the dysplastic sequelae in this type of hip malformation, and probably is developing in this case.

FIG. 2-B

FIG. 2-A

Fig. 2-A: Roentgenogram taken in October 1945, when the child was one year of age, revealed a flat, shallow dysplastic acetabulum with pronounced subluxation of the femoral head from the socket. There was delayed and hypoplastic development of the ossification center of the femoral head. She walked with a slight limp. Clinical examination of the left hip joint demonstrated shortening of the extremity, slight telescoping, and limitation of abduction. Abduction treatment was refused.

Fig. 2-B: Roentgenogram, taken in April 1948, revealed normal structures of the left hip joint, except for slight hypoplasia and irregularity of the nucleus of the head. Clinically the hip joint and extremity were normal. There had been no treatment since the examination in 1945.

This is the only case of spontaneous healing of congenital dysplasia of the hip joint with displacement ever seen by the author. Probably this phenomenon is common during prenatal life and early infancy. (Courtesy of Dr. H. J. Fortin, Fargo, North Dakota.)

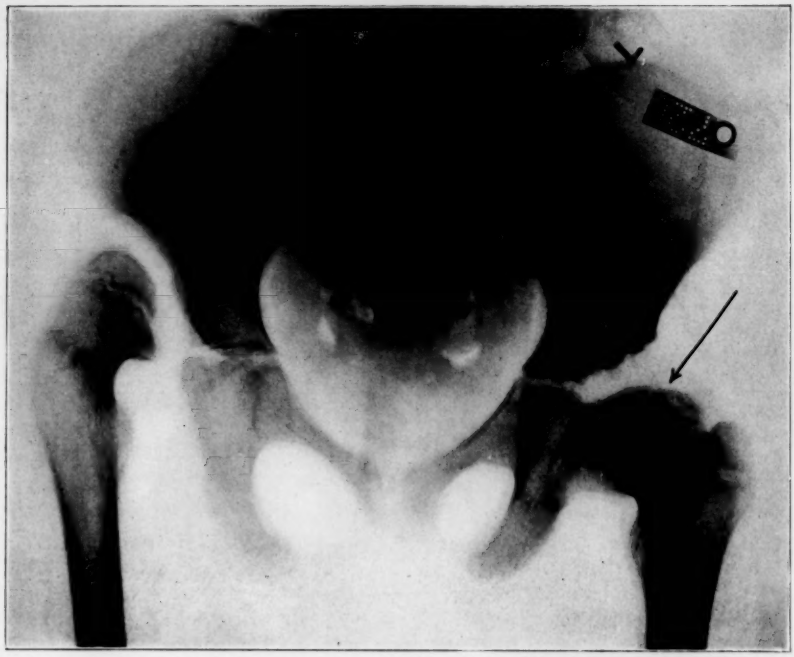

FIG. 3

Classical congenital dislocation of the right hip and congenital subluxation with coxa plana of the left hip. Neither hip joint had been treated. The irregular and delayed calcification of the femoral head may be an expression of epiphyseal dysplasia.

FIG. 4

Congenital subluxation of right hip joint with evidence of coxa plana or epiphyseal dysplasia. This child had never been treated. The patient's aunt had congenital dislocation of the hip.

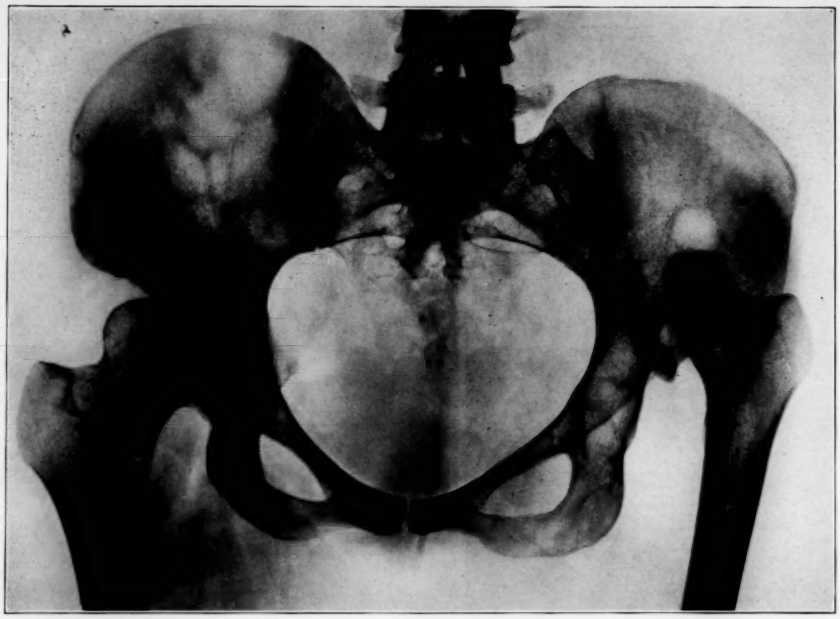

FIG. 5

This patient, twenty-four years of age, had had no trouble with the right hip until two weeks before examination, when she strained it while bowling. Observe the primary flat socket with secondary subluxation and early traumatic osteo-arthritis of the right hip, and classical dislocation of the left hip joint. The dislocated left hip is painless; the subluxated right hip is painful. The patient's hip joints had never been treated. This patient's mother has congenital subluxation of one hip with extensive osteo-arthritis.

The characteristic forms of the subluxated and the dislocated femoral heads may be seen. In subluxation the head is hypertrophied. It is widened in its transverse axis and flattened in its vertical axis. It may represent the adult stage of coxa magna or late deformity of epiphyseal dysplasia. In dislocation the femoral head is small and atrophied.

caused by an osseous and cartilaginous defect, or by aplasia of the superior and posterior supports or buttress for the head of the femur. The author believes that this defect has a genetic or biomechanical etiology, or a combination of the two, and that it is a constant primary malformation in congenital dysplasia of the hip. Primary dysplastic features are not limited to the acetabulum, but may involve all mesodermal structures of the hip joint. The many secondary pathological features or dysplastic sequelae which develop gradually during a period of months or years may be explained on the basis of laws of bone growth, aseptic necrosis of bone and cartilage, and traumatic osteo-arthritis.

For many years, physicians have been interested in explaining the form and structure of the normal and the abnormal hip joint. Keith wrote that, in 1838, Mr. F. O. Ward, who demonstrated anatomy at King's College, London, explained for the first time the architecture of the femoral head and neck. He compared the two groups of bone trabeculae in the femoral neck with a triangular bracket supporting a street lamp, the ascending supports being subjected to pressure and the horizontal supports to tension. The architecture of the femoral neck is a perfect mathematical design for the transference of weight. Keith states: "Hunter discovered that the elaborate architecture of the neck was being continually remodelled from infancy to adult life; without such remodelling, the femoral shaft could not grow". A study of the head and neck of the femur gave Wolff the key to his law of bone transformation, which he expressed in 1885.

The shape and form of normal and abnormal hip joints have been investigated by

FIG. 6-A

In addition to the characteristic features of primary hip dysplasia with acclivity of the acetabular roof, secondary changes of subluxation and traumatic osteo-arthritis with loss of joint space, sclerosis, cystic rarefaction, and double acetabular floor are present. The patient's symptoms began at the age of forty. She was totally disabled for work and was not relieved by conservative measures. The hip was treated by arthrodesis. Her sister is disabled with bilateral hip dysplasia and dislocations.

many physicians over the years. Keith has stated that the osteoblasts, influenced by static and dynamic forces, are the engineers of the hip joint and do their work according to exact mathematical laws. A study of the pathogenesis of congenital subluxation and congenital dislocation of the hip joint from the foetus through adult life explains many of the interesting phenomena of bone and cartilage growth.

Evidence to support the common etiological relationship between subluxation and dislocation is available from many sources:

1. *The Literature*

For many years, physicians believed that subluxation was only the precursor of dislocation; and that a subluxation never remained stationary throughout life, but always progressed to complete displacement. According to Wiberg, the term "subluxation" was introduced by Paletta in 1775, on the basis of autopsy findings. Parise recognized the distinction between complete and incomplete dislocation in 1842. Sayre, in 1876, wrote: "The real difficulty in this condition, which has been termed congenital dislocation, but which I prefer to call congenital misplacement, consists in the *malformation* of the acetabulum, namely, a non-fusion of the three bones which enter into its construction. The cavity of the acetabulum being incomplete, the head of the femur rides through the opening left, and is found upon the dorsum of the ilium." According to Wiberg, the first publication of a case of subluxation on the basis of clinical and roentgenographic findings was by Zenker in 1897. Wiberg also stated that Hoffa and Lorenz believed that subluxation was a transitional stage, and that dislocation would always result as the child started to bear weight. As late as 1937, Albee stated: "The dislocation may be *complete* or *incomplete*.

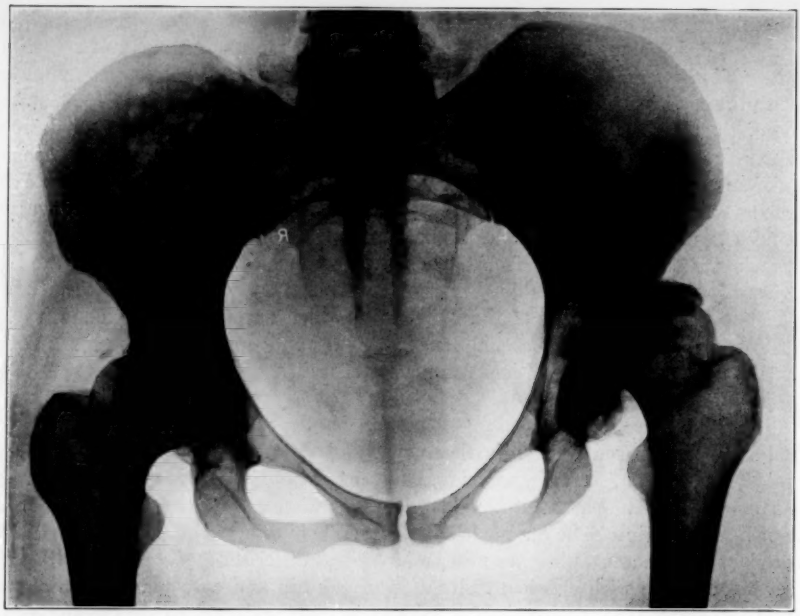

FIG. 6-B

Roentgenographic study of a housewife, forty-six years of age. Pain started in the left hip at the age of twenty-five; in the right hip, at the age of thirty-one. She continues with her work and does not use a cane or crutch. Pain and disability of the left hip are increasing gradually. The patient's brother has congenital dislocation of both hips.

The primary dysplastic features involve both acetabula, which are flat and inadequate. The secondary pathological changes of subluxation, malformation or coxa magna of the femoral heads, and traumatic osteo-arthritis, which is extensive on the left side, may be noted. Shenton's line is disturbed on each side. (See Fig. 10.)

The latter, in which the head is not entirely out of the acetabulum, is only a step in the process."

Albert Freiberg, in 1904, published the first and one of the most valuable studies in this country of congenital subluxation of the hip in infancy. The first demonstration that subluxation could remain during life as a definite and disabling entity was made by Gourdon in 1906. Gradually more and more surgeons reported their clinical experiences and belief that subluxation was not only the forerunner of dislocation, but that it frequently remained as a stationary deformity and a disease entity. The monumental work of Putti firmly established subluxation as a distinct clinical, pathological, and roentgenographic entity. He pointed out that recognition of subluxation and its treatment in the infant, before weight-bearing begins, is "the only secret that can improve the results of the treatment of congenital dislocation of the hip" (Figs. 8-A and 8-B).

Howorth and Smith, in 1931, reported a detailed study of seventy-two congenital dislocations treated by open operation. They stated: "Seven per cent. of the hips were only subluxated . . . and ninety-three per cent. were completely dislocated". Gill, in his many excellent contributions on congenital dislocation of the hip, has described the morbid anatomy of congenital subluxation and the surgical treatment by acetabular reconstruction.

In 1932, Colonna published his method of arthroplasty for congenital dislocation and subluxation. Since then he has made careful follow-up studies; a report of the end results was published in 1947. Colonna's two-stage procedure for obtaining functional hips in children under eight years is an important contribution.

Joseph Freiberg, in 1934, wrote a very instructive paper on the early recognition and treatment of dislocation, in which he stated: "Up to 6 months of age, and sometimes until the walking period, the dislocated femoral head lies lateral to the acetabulum and level with the superior margin of the acetabulum". McCarroll and Crego, in 1939, stated: "Three distinct types of congenital dislocation can be clearly recognized and differentiated. The first of these is the classic posterior dislocation. . . . The second type consists merely of an upward subluxation. . . . The third type of dislocation is that which exists in a true anterior position. . . ." (This is actually a superior dislocation with anteversion of the neck.) In 1939, Wiberg wrote an excellent review of the history of subluxation. Ryerson, in 1941, described his shelf operation for "congenital subluxation of the hip" and other conditions with instability of the hip joint. Ponseti, in 1944, classified five types of congenital dislocation of the hip, one of which he described as follows: "The subluxation, where, in spite of a shallow acetabulum and upward displacement of the head of the femur, a complete dislocation never occurs".

2. *Clinical Histories*

It has been observed frequently that congenital dislocation of the hip, coxa plana, coxa valga, subluxation, coxa magna, and malum coxae senilis may affect various members of the same family. The parent of a child with dislocation may have arthritis deformans of one or both hip joints. The author has seen several children with Legg-Perthes disease or coxa plana, whose aunt, uncle, or other relative had dislocation of the hip. He has also seen several children with classical dislocation of one hip and coxa plana or epiphyseal dysplasia involving the "healthy" hip. Jansen, in 1923, referred to coxa plana as the "satellite" of congenital dislocation of the hip (Figs. 3 and 4). It is not uncommon to see an adult with a painless untreated congenital dislocation of one hip and a painful subluxation of the opposite hip which, for years, had been considered normal, until an acute strain or traumatic osteo-arthritis developed (Fig. 5). A frequent experience is to observe a patient with congenital subluxation, who has a relative with congenital dislocation (Figs. 6-A and 6-B). It is little wonder that many writers have considered a hereditary etiology for these various diseases of the hip joint. Not until 1937, however, was a truly scientific study made by Faber to determine their hereditary nature.

3. *Clinical and Roentgenographic Examinations*

It is unusual to observe dysplasia of the hip with some degree of displacement or subluxation in a child, unless the child is under treatment for dislocation of the opposite hip. There are no subjective symptoms or objective clinical findings during infancy in hip-joint dysplasia without displacement of the femoral head. However, dysplasia with subluxation, which is often the precursor of dislocation, can be recognized in the infant (Figs. 7-A and 7-B) or later, after the child begins weight-bearing, as a dislocation or as a pronounced subluxation. The displacement must be considered a subluxation as long as some contact remains between the femoral head and the articular surface of the dysplastic and inadequate acetabulum. Waldenström stated: "By subluxatio coxae congenita we understand a condition which may be best characterised by the words: 'on the way to luxation'." Dislocation occurs when the displacement increases and there is no contact of articular surfaces of femoral head and sloping socket.

The infant with subluxation presents well-known clinical and roentgenographic changes by which the condition may be diagnosed. In every instance these signs may be demonstrated before the fourth month of life or before the appearance of the epiphyseal nucleus of the femoral head. These infants' hips will either progress to dislocation or remain in severe subluxation without treatment, unless spontaneous recovery occurs.

At a later age during childhood, because the child complains of hip fatigue, pain, and limp after exertion, dysplasia of the hip with coxa plana or aseptic necrosis of the femoral

FIG. 7-A

FIG. 7-B

Fig. 7-A: Six-week-old male infant with congenital subluxation of the right hip joint. Clinical examination demonstrated marked limitation of abduction of the hip because of adductor contractures, slight shortening, and asymmetry of the thigh folds and creases. There is delayed ossification of the ischiopubic juncture on the right.

Fig. 7-B: Roentgenogram four and one-half months later, no treatment having been given. The clinical findings have not changed. The roentgenographic features of congenital dysplasia of the right hip with subluxation are obvious. Observe (1) the flat and inadequate socket with sloping acetabular roof, (2) delayed development of the center of ossification of the femoral head, (3) delayed closure of the right ischiopubic juncture, (4) slight upward and lateral displacement of the femoral head from the socket, (5) position of adduction of the right lower extremity because of adductor contractures, and (6) the disturbed Shenton line. (Draw the Y line [Hilgenreiner] and the vertical line [Perkins] to form the quadrants and observe the relationship of the nucleus of each femoral head to these lines and the quadrants.)

FIG. 8-A

FIG. 8-B

Fig. 8-A: Abduction pillow splint which Professor Frejka, of Czechoslovakia, demonstrated before the Annual Meeting of The American Academy of Orthopaedic Surgeons in 1947. Complete abduction and complete reduction are gradually accomplished by the continuous pressure of a pillow, filled with down or kapok, which is placed between the two layers of the splint. Medium-weight cotton twill or mattress ticking is the best material for making the splint. Soiling is prevented by placing waterproof material between splint and diapers. The splint is efficient and inexpensive, and provides active instead of passive immobilization. The active muscular function which is permitted in this splint prevents atrophy, contractures, and adhesions. Certainly the physiological stimuli of normal pressure and motion must enhance the potential capacity for reforming the flat and dysplastic socket, in accordance with the laws of bone growth.

Fig. 8-B: Back view of the Frejka splint. Standing and walking are encouraged at the proper time.

FIG. 9

Note the characteristic features of primary dysplasia of the acetabulum (Calot's half-citron socket). There is physiological adaptive sclerosis of the acetabular roof or very early osteo-arthritis. Note the disturbance of Shenton's line. The patient, a young woman, complained of hip fatigue and a mild limp when tired. Symptoms were completely relieved by rest and change of occupation. The opposite hip is normal. The patient's sister is disabled by a hip dislocation.

head may be found (Figs. 3 and 4). During late adolescence and early adult life a dysplastic hip is frequently observed, because of attacks of hip pain with limp and atrophy of the thigh. There may be no limitation of hip motion or shortening of the extremity. Only by roentgenographic studies is the dysplastic flat, citron-shaped socket recognized (Figs. 9 and 10). The earliest finding of osteo-arthritis—increased sclerosis of the weight-bearing portion of the acetabulum—may be found at this time, in addition to the primary features of hip-joint dysplasia with slight or pronounced subluxation.

In middle life, advanced osteo-arthritis may develop secondary to subluxation, and cause serious disability (Figs. 6-A and 6-B).

4. *Roentgenographic Studies of the "Normal" Hip in Patients with Unilateral Classical Dislocation*

The most convincing evidence of relationship between subluxation and dislocation is found in patients who have positive roentgenographic findings of both entities, involving the two hip joints (Figs. 11 and 12). Wiberg wrote that Hoffa had made this observation in children, but had stated that the subluxation would always develop into a dislocation as the child grew. Wiberg also stated that, as early as 1900, Bade found hypoplasia of the roof on the "healthy" side in 25 per cent. of unilateral dislocations, "and he thought that the more careful technic of the future would leave hardly any unilateral cases". Severin reported, in 1941: "Re-examination of the original roentgen pictures showed that 57 of the 'healthy' hips in 190 unilateral cases suffered from definite dysplasia or subluxation when the other was treated". Ponseti, in 1944, studied the so-called normal hip in eighty-five cases of unilateral dislocation. He observed that the "normal" hip was well

FIG. 10

Roentgenographic study of a twenty-year-old physical-education student, who had no complaints except mild pain and a feeling of fatigue, involving the region of the left hip, following strenuous exercise. Observe the bilateral flat dysplastic socket with mild subluxation of the right femoral head and pronounced subluxation of the left femoral head. The absence of coxa magna deformity of the femoral heads may be evidence that epiphyseal dysplasia did not exist during the growth period. The disturbance of Shenton's line is slight on the right side, but marked on the left. Gradually over the years traumatic osteo-arthritis will develop in both hip joints because of their dysplastic incongruity and malformation. (Courtesy of Dr. E. F. Chambers, Seattle, Washington.)

formed in forty-seven cases, and in the remainder, it showed some defect as proof of its congenital dysplasia. No one knows what percentage of these well-formed hips had been changed from a state of dysplasia to normal by spontaneous recovery, without benefit of special treatment.

Fairbank observed in 1929: "Many surgeons, however, including myself, have been impressed with the frequency of pain and other signs of arthritis in a congenitally unstable or subluxated joint previously regarded as normal, while the opposite hip, completely dislocated, gives no trouble". Waldenström, in 1932, stated: "It is of fairly common occurrence that a luxatio congenita on the one side occurs together with a subluxation on the other". Jansen, in 1929, discussed coxa plana involving the "normal" hip in children with unilateral dislocation of the opposite hip. The author has had the same experience and believes that aseptic necrosis of the femoral head or epiphyseal dysplasia may be one of the many consequences or expressions of hip-joint dysplasia (Figs. 3 and 4).

While reviewing the literature on hip-joint dislocation, one observes a large number of illustrations which demonstrate a markedly flat or dysplastic hip with varying degrees of subluxation involving the "normal" hip. The high incidence of coexistence of dysplasia with dislocation of one side and dysplasia with subluxation of the opposite hip is convincing evidence of a relationship or common etiology of the two entities (Figs. 11 and 12).

5. *Observations of Residual Subluxation*

Residual subluxation is a partial displacement of the femoral head from the socket, subsequent to closed or open reduction of a dislocation. This is a common complication

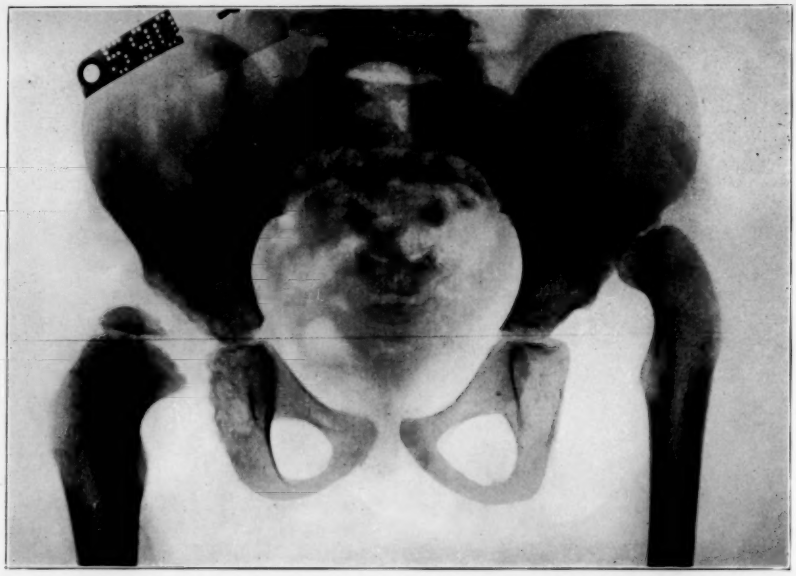

FIG. 11

The most convincing evidence of relationship between congenital subluxation and congenital dislocation is found in patients who have positive roentgenographic findings of both entities, involving the two hip joints.

Roentgenogram shows bilateral dysplasia of the hip joints in a child, six years of age, with dislocation of the left hip and subluxation of the right hip. The hips had never been treated. The right or subluxated hip caused no complaints and had been considered "normal". (See Fig. 12.)

following reduction, but one to be expected if later there is insufficient development of the acetabular roof. If the residual subluxation does not continue toward displacement with weight-bearing, but remains a fixed and permanent condition, it may then be compared with the congenital subluxation which also is fixed and permanent. The two conditions are now the same in many anatomical and mechanical features. One would not expect them to be identical, because of the more marked secondary changes which had developed in the ligamentum teres, Haversian gland, capsule, limbus, femoral shaft and neck (antetorsion), and femoral head on the dislocated side before reduction, but they continue to have a similar clinical course throughout life. There is usually good stability and function during childhood, adolescence, and early adult life, but during middle adult life serious disability begins. Osteo-arthritis is then superimposed, because of the trauma of instability and the incongruity of the functioning articulation over the years. At this stage the clinical, roentgenographic, and pathological features of arthritis deformans are the same in the two entities.

6. *Arthrographic Studies*

Arthrographic studies should be reserved for scientific research. Clinical and roentgenographic findings are sufficiently accurate for all practical purposes. Arthrographic studies, however, have added a great deal to our knowledge of the normal and the pathological hip joint. Severin, Faber, Leveuf, Wiberg, Stewart, and others have made important contributions.

7. *Genetic, Embryological, and Anthropological Investigations*

The writer is familiar with only one genetic investigation which provides accurate and scientific evidence of a relationship between subluxation and dislocation of the hip.

Faber, in 1937, reported his roentgenographic consanguinity studies of the families of ten children with classical dislocations, who were considered ostensibly sound in their heredity. All genetic studies made prior to Faber's monumental contribution had been founded on the concept that the dislocation was the inherited trait. They had been based only upon the data of actual clinical dislocations of patients whose parents or relatives also had dislocations. Faber based his concept on the fact that the hereditary factor, upon which dislocation depends, is not the hip dislocation itself, but instead is a primarily existent defect in the joint, designated by Hilgenreiner as congenital dysplasia of the hip joint or a flat socket. Subluxation, as well as dislocation, is a consequence of the primary genetic dysplasia or incompetent acetabulum.

Previous authors had agreed that, in 20 per cent. of all cases of dislocation of the hip, they observed a genetic occurrence in families. The anatomy of the hip joints of all persons having blood relationship could not possibly have been evaluated properly unless clinical and roentgenographic studies of the hip joints of each individual had been available. Faber demonstrated that, in the families which he investigated roentgenographically, primary dysplasia of the hip with subluxation was three times as frequent as was classical dislocation. He also found dysplasia with osteochondrosis deformans in children and malum coxae senilis or arthritis deformans in middle life, findings which coincide with observations in clinical practice. The writer has observed that subluxation, like dislocation, is more common in the female.

Embryological studies have added no positive evidence to our understanding of congenital dysplasia of the hip joint, although work in this field, such as that of Strayer, should be encouraged.

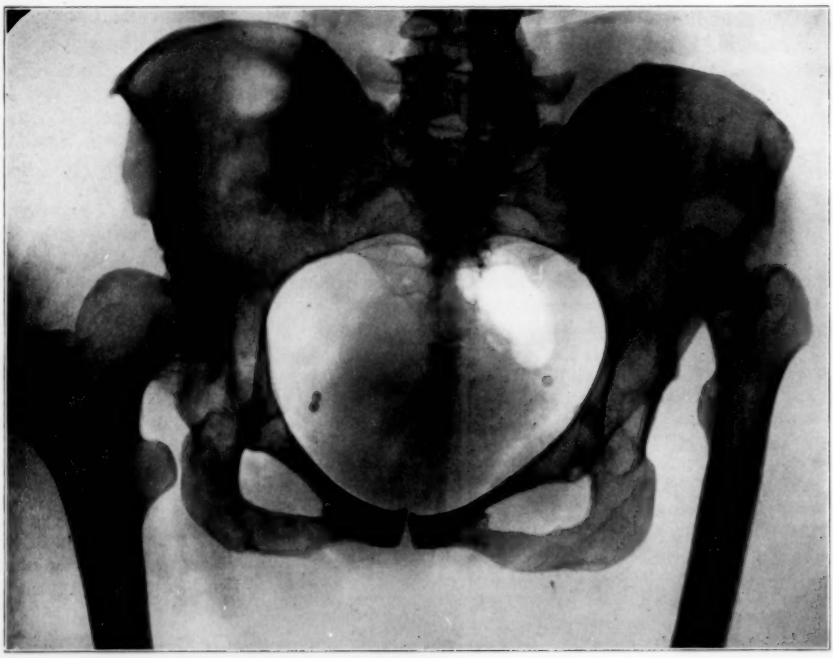

FIG. 12

Bilateral dysplasia of the hip joint in an adult, thirty-eight years of age, with dislocation of the left hip and subluxation of the right hip. The hip joints had never been treated. The subluxated hip had been considered "normal" until the age of thirty-six, when pain first appeared because of traumatic osteo-arthritis. The characteristic hypertrophy or coxa magna of the subluxated femoral head and atrophy of the dislocated head are visible.

Böhm, in 1932, stated: "We know clinically that the infantile deformities have a tendency to familial and hereditary appearance and that anatomically their morphological substratum is identical with the normal conditions of certain animals, such as the anthropoid. . . . The acetabulum of the human foetus shows the same characteristics as that of the gorilla . . . the posterior roof is entirely lacking. . . . The human foetus has likewise an acetabulum of oval shape. Thus I consider the infantile deformities as congenital in a wider sense."

8. *Pathogenesis of Arthritis Deformans*

Preiser, in 1907, first mentioned that congenital subluxation was the most important etiological factor in the development of osteo-arthritis of the hip joint. Putti, in 1933, stated that 40 per cent. of all cases of arthritis deformans of the hip or malum coxae senilis are the result of congenital subluxation. Wiberg, who observed the development of osteo-arthritis in nineteen cases of congenital subluxation, believed that in about every fourth hip with arthritis deformans the condition is originally due to subluxation (Figs. 6-A and 6-B).

9. *Surgical Observations*

At the time of open reduction for acetabular reconstruction or arthroplasty in children, one frequently finds some contact between the articular cartilage of the femoral head and the articular cartilage of the acetabulum. The femoral head lies against the deficient portion of the roof and limbus of the socket. There is no isthmus of the capsule. It is rare to observe a constriction of the capsule between the acetabulum and the femoral head before the age of three years. The head is on its way to dislocation, but the actual pathological finding is subluxation, secondary to dysplasia of the hip and slight stretching of the capsule. This is a common observation at open reduction before the age of four years; it would be a very common finding if one opened the hip joints of infants before the age of weight-bearing.

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DISCUSSION

DR. PAUL C. COLONNA, PHILADELPHIA, PENNSYLVANIA: A clear differentiation of the two manifestations of hip dysplasia, to which Dr. Hart has again called our attention, has long been present in the writings of the European surgeons. We have at this meeting one of the outstanding authorities on this interesting subject, Professor Leveuf. I hope he will comment on this paper. Dr. Hart had to delete a part of his paper because of lack of time, but I should advise a careful study of it when it is published.

He and others have defined true congenital dislocation as a condition in which the head is not in contact with the acetabular cartilage, while in incomplete dislocation, or subluxation of the hip, some contact with the cartilage is retained, without capsular interposition. Gourdon stated over forty years ago that he believed subluxation to be a relatively stable condition that never developed into luxation. Some of us may question this in the light of our personal experience, but certainly we would agree with Dr. Hart that subluxation should never be regarded as *only* a transitional stage of dislocation. We believe that in the great majority of subluxated hips, the condition remains essentially stationary. The widening of the joint space, the limitation of abduction, and the slight upward riding of the greater trochanter can be recognized quite early, and Putti stressed the use of abduction as a simple curative measure in young infants.

The shadow representing the nucleus of the head is not visible at birth, and its development is delayed in the dislocated hip. In my opinion, it is only after the third or fourth month of life that one can begin to recognize definitely the presence of subluxation of the hip from the roentgenograms.

Professor Leveuf has shown, by the use of arthrograms, that the cotyloid cartilage or limbus is forced upward, producing a flat saucer-like socket in the cases of subluxation, while there is a cartilaginous cuff

along the superior rim in the cases of luxation or dislocation. This probably will add greatly to our information regarding not only dysplasia of the hip, but also other non-infectious conditions.

In a recent Scandinavian journal, Gade cited 123 osteo-arthritic hips which had been operated upon, 47 per cent. of which presented some degree of congenital dysplasia. This means that the recognition of these hip dysplasias and their immediate treatment is very important.

We would like again to congratulate Dr. Hart on stressing the matter of early recognition and pointing out various aids in the differentiation of the two entities, both of which are the result of a primary genetic dysplasia of the joint. We have, in addition, been impressed with other congenital anomalies that have been found in cases with frank dislocation. The frequent lack of fusion of the fifth lumbar or upper sacral segment, noted in the older child, indicates that the congenital maldevelopment is often not limited to the hip-joint structures.

We would like to reiterate the danger of our attention becoming focused upon the frankly dislocated hip, while the subluxation or incomplete dislocation of the opposite hip is disregarded. We should remember that both hips are sources of potential trouble and need proper care.

Dr. H. Relton McCarroll, St. Louis, Missouri: No one doubts the existence of the upward subluxation as a developmental defect in these hips. Although Dr. Hart did not have time to present his entire paper, I believe he is trying to cover too much territory with his theories regarding this anomaly.

I would like to limit my discussion primarily to three points. First, I believe that upward subluxation of the hip is not so common as Dr. Hart indicates. There are three primary types of dislocation,—the primary posterior dislocation, the primary anterior dislocation, and the simple upward subluxation. In our series of 111 cases seen between 1935 and 1945, we had sixty-eight primary posterior dislocations, twenty-five primary anterior dislocations, and eighteen upward subluxations.

The second point has to do with the diagnosis of an upward subluxation at the time of birth. Any one who is accustomed to examining these infants or seeing their roentgenograms is fully aware of the tremendous variation that exists in these hips in normal individuals. I am not sure that these variations or characteristics are invariably indicative of an upward subluxation. We have seen hips of this type in which we have been unable to demonstrate instability, have followed the patients, with repeated x-ray studies, and have found that often these findings disappeared spontaneously. In a high percentage of cases, in fact, these hips will be normal at the end of one or two years without any treatment.

The third point concerns the assumption of a genetic relationship in this type of involvement. One may suspect it, but there has been no scientific evidence or proof of genetic influence on these various developmental defects. I think it has to be entirely discarded in the light of our present knowledge.

I would like to ask Dr. Hart how he can be sure that there are many types of intra-uterine dislocation of the hip.

Mudr. Jaroslav Slavik, Prague, Czechoslovakia: I have three remarks to make. First, Dr. Hart is right when he says that congenital displacement of the hip is very common. Statistics determined at Charles University (in Pilsen and Hradec Králové) during the last two years have disclosed that fully 20 per cent. of newborn infants were afflicted with congenital dysplasia of the hip of a greater or lesser degree. Because of this extremely high rate, nearly every newborn child in the university towns in our country is submitted to x-ray studies of the hip at the age of three weeks and again at the age of three months. We believe that we recognize this disease sooner than the period of middle adult life, and sooner than Dr. Hart claims he recognizes it. Very often there is first preluxation, which develops into subluxation and finally into luxation in the same hip.

Second, Dr. Hart says that in congenital displacement of the hip, sometimes under the influence of function, a normal hip joint develops. He has based this opinion only on the normal x-ray picture, but microscopically I have found abnormal changes. I have a book of seventy-five microscopic specimens of ligamentum teres which were removed in a series of 150 consecutive open reductions for congenital dislocation of the hip, fractures, and Perthes' disease. I found, for instance, that between the ages of seven and sixteen, an acute rupture of the ligamentum teres or an acute second stage of obliteration of the blood vessels of the ligamentum teres occurs. At this time the epiphyseal cartilage still remains open, and the head of the femur is extremely vulnerable to slight trauma. The age from seven to sixteen is the period at which Legg-Perthes disease develops. I believe that this disease occurs only in congenital displacement of the hips.

Third, in Europe we use the term "preluxation" as indicating the precursor of classical subluxation. We find in this condition (1) a poorly developed shelf of the socket, and (2) delayed development of the ossification center of the head of the femur. There are, however, more than two clinical manifestations of the same genetic dysplasia.

Dr. Vernon L. Hart (closing): Dr. McCarroll is correct that a scientific genetic study has never been made in this country. Any such study requires roentgenographic consanguinity tests, such as those made by Faber in 1937.

(*Continued on page 384*)

INJURIES OF THE LATERAL LIGAMENTS OF THE ANKLE

A Clinical and Experimental Study*

BY MORTON H. LEONARD, M.D., COLUMBIA, MISSOURI* *

From the State Crippled Children's Service, University Hospitals †, Columbia

Spontaneously reduced subluxations of the ankle often masquerade as sprains[1-7]. They are frequently undertreated by local procaine infiltration and adhesive strapping, with prolonged temporary and occasionally permanent disability for the patient. On the other hand, the author believes that the plaster immobilization which these injuries require is often prolonged unduly. To clarify the relative importance of the lateral ligaments in maintaining ankle stability and for better visualization of the mechanism of inversion injuries to these ligaments, a series of cadaver experiments were performed.

CLINICAL FINDINGS

Fifty-one cases of inversion injury of the ankle were studied. Twenty-three patients were shown roentgenographically to have had spontaneously reduced subluxations. In all instances, both ankles were x-rayed in inversion following general or local anaesthesia, and a difference in the degree of parallelism between the articular surfaces of the talus and of the tibia on the two sides was considered diagnostic of a spontaneously reduced subluxation of the ankle[1,2,5]. When the condition was diagnosed as subluxation, the ankles were immobilized in skin-tight walking plasters for six weeks. These casts were kept skin-tight, as the swelling subsided and the muscles underwent atrophy, by changing them approximately every three weeks. The patients, all college students, were able to attend their classes, and the more aggressive danced and even bowled while so immobilized.

Following removal of the plaster, the foot and ankle were wrapped with elastoplast for about two weeks, principally to minimize the oedema; and roentgenograms were then taken with the ankles in forced inversion. The follow-up roentgenograms showed completely stable ankles in all twenty-three cases.

In twenty-four cases the ankles were stable roentgenographically and were treated by procaine injection and adhesive strapping. Seven of these twenty-four patients had persistent disability, complaining of swelling and a feeling of insecurity, as well as of pain over the anterior talofibular ligament, for as long as they were followed (two to five months).

Four were cases of recurrent injury. The ankles were grossly unstable, as a result of inadequate treatment of acute injury in the past. One man, twenty-five years old, with a ten-year history of repeated inversion of the ankle, already showed clinical as well as roentgenographic evidence of traumatic arthritis, in addition to gross ankle instability.

Some, including Watson-Jones, advise at least ten weeks of immobilization before an acute instability of the ankle is treated. The writer believes that this is too long. With the disappearance of ecchymosis and ligamentous tenderness being used as an index, all but a few of the twenty-three patients treated for acute injury required six weeks of plaster encasement. These few ankles were kept in plaster one or two weeks longer. As noted previously, this period of immobilization, followed by two or three weeks of strapping with elastoplast, gave stable, symptom-free ankles in all twenty-three cases treated.

From the literature, the writer could not determine the relative importance of the

* Presented at the Meeting of the Chicago Orthopaedic Society, March 12, 1948.

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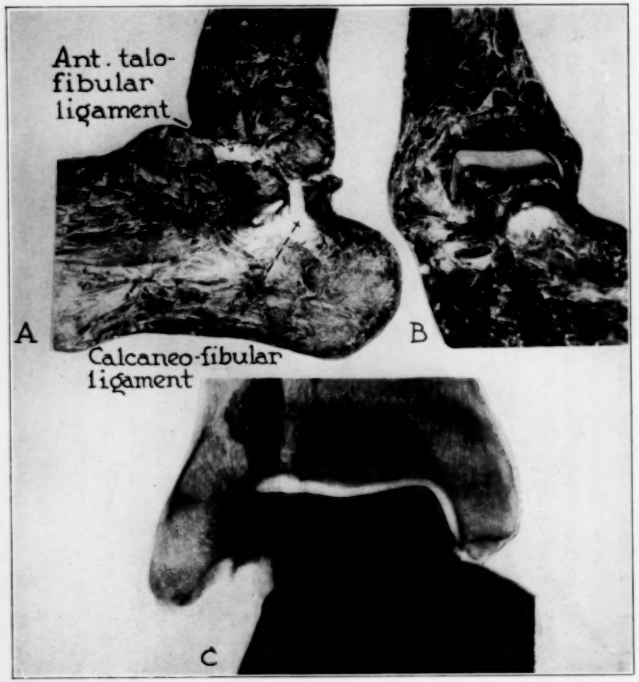

FIG. 1

A: Course of the lateral ligaments with the foot at an angle of 90 degrees with the leg.
B: Inversion of foot at 90 degrees.
C: Ligaments are intact. Note the minimal instability (5 degrees). Clinically, this is important if the other ankle is stable [2].

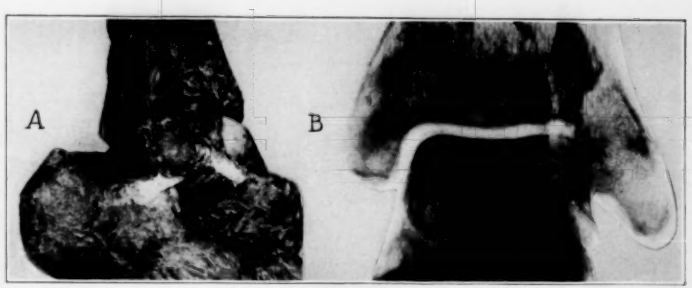

FIG. 2

A: Course of ligaments with foot in equinus.
B: Inversion of foot in equinus with ligaments intact.

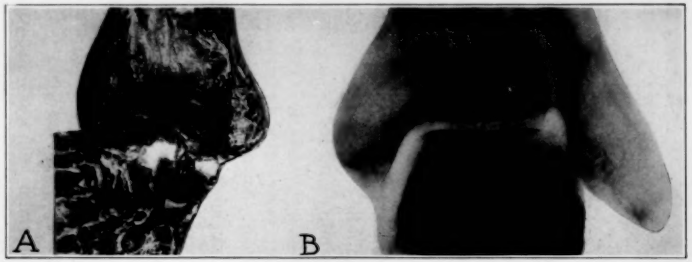

FIG. 3

Anterior talofibular ligament has been cut and inversion is at 90 degrees.
A: In photograph, note the instability in the axis of the tibia (angle *T* is 10 degrees) as well as in the long axis of the talus (angle *A* is 10 degrees). (See Fig. 4, *C*.)
B: This roentgenogram was made on a different cadaver, which showed no instability.

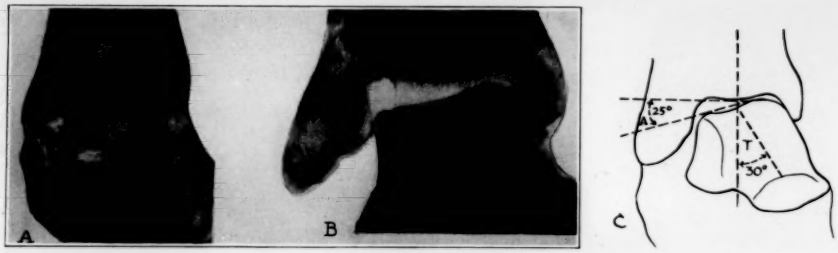

FIG. 4

Anterior talofibular ligament has been cut and foot is inverted in equinus.

various components of the lateral ligaments in maintaining talotibial stability. Most authors state that the calcaneofibular ligament is the most important, that it ruptures most commonly, giving the greatest degree of instability [1,2,3,5]. Pennal, in the illustrations of his article, showed that cutting the calcaneofibular ligament of a fresh cadaver resulted in about 4 degrees of ankle instability by roentgenogram; but that cutting the anterior talofibular ligament gave 12 degrees. As a corollary, we wonder in what position the foot should be inverted (at 90 degrees or in equinus) to show maximum ankle instability.

EXPERIMENTAL FINDINGS

In order to visualize the mechanism of inversion injuries resulting in ligamentous

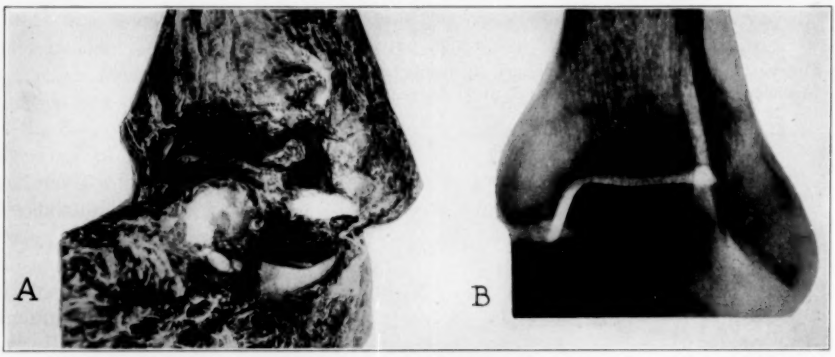

FIG. 5-A

Calcaneofibular ligament has been cut and foot has been inverted at 90 degrees. Note tibiotalar stability, increase of subtalar motion.

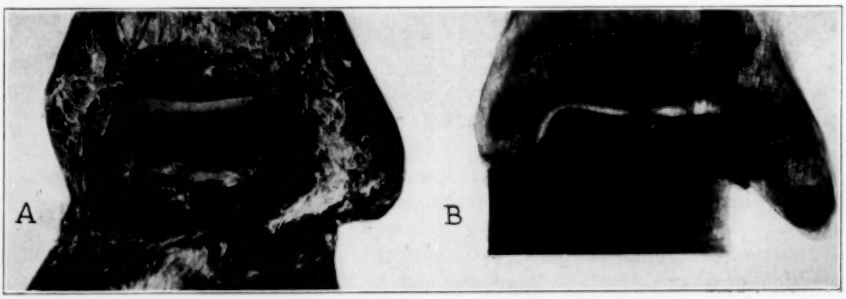

FIG. 5-B

Same specimen, as shown in Fig. 5-A, in equinus.

FIG. 6

Anterior talofibular and calcaneofibular ligaments have been cut.
A: Note gross instability, shown in photograph.
B: Inversion, with foot at 90 degrees. *C:* Inversion, with foot in equinus.

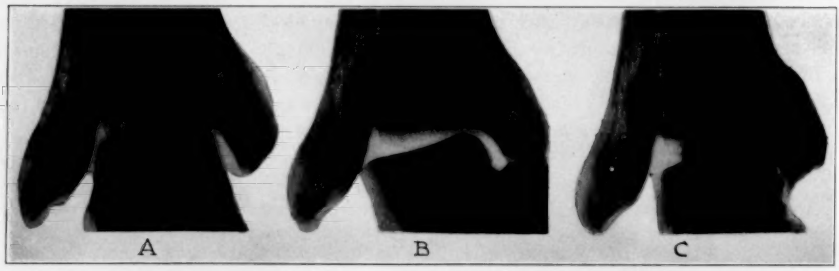

FIG. 7

Posterior talofibular and calcaneofibular ligaments have been cut.
Inversion, with foot: *A*, in equinus; *B*, at 90 degrees; and *C*, in hyperextension.

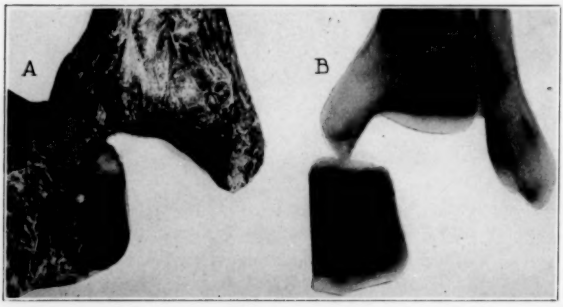

FIG. 8

All three ligaments have been cut.

damage, and to assess the importance of a given ligament in the maintenance of talotibial stability, seven preserved ankles were stripped of their soft parts, the collateral ligaments being retained. Observations were made first of the course of the ligaments in varying degrees of plantarflexion and dorsiflexion, and then of the effect of cutting the ligaments in various combinations on ankle stability in equinus, at 90 degrees, in dorsiflexion, and in extreme dorsiflexion. Photographs and roentgenograms were taken.

With the foot at an angle of 90 degrees with the leg, the calcaneofibular ligament is perpendicular and the anterior talofibular ligament is parallel to the long axis of the talus. Therefore, inversion in this position results in strain on the calcaneofibular ligament (Fig. 1).

However, most ankle inversions occur with the foot in plantar-flexion during forward propulsion, or when the patient is wearing high heels. With the foot in equinus, the calcaneofibular ligament is parallel and the anterior talofibular ligament is perpendicular to the long axis of the talus (Fig. 2). From this, it can be deduced that the anterior talofibular

ligament is the one most commonly injured. This is also true clinically. In almost all of the fifty-one cases studied, tenderness was present over the anterior talofibular ligament.

After the anterior talofibular ligament has been cut, the ankle is relatively stable at 90 degrees, since the wide portion of the talus is engaged in the ankle mortise (Fig. 3). With the foot in equinus, the ankle is less stable (Fig. 4). In addition to the instability in the long axis of the talus, there is also instability around the vertical axis of the talus.

When the calcaneofibular ligament has been cut and the ankle has been inverted at 90 degrees, there is increased motion in the subtalar joint, but the tibiotalar relationships remain practically the same (5 degrees) (Fig. 5-A). The ankle is stable in equinus (Fig. 5-B).

With both the calcaneofibular and the anterior talofibular ligaments cut, there is marked instability both in the weight-bearing and in the long axis of the talus (Fig. 6).

Cutting the posterior talofibular ligament permits extreme dorsiflexion, but the ankle remains stable. With both the posterior talofibular and the calcaneofibular ligaments cut, even more dorsiflexion is possible. At 90 degrees there is instability of about 10 degrees in the long axis of the talus, but the ankle is stable in equinus (Fig. 7).

When all three ligaments have been cut, the ankle is grossly unstable (Fig. 8).

From these experiments the author concludes that the anterior talofibular ligament is the most frequently ruptured and the most important component of the lateral ligaments of the ankle. Inversion films should be taken in equinus, if the tenderness is anterior to the fibula; and at 90 degrees, if the tenderness is posterior to the fibula.

SUMMARY AND CONCLUSIONS

1. In a series of fifty-one severely "sprained" ankles, twenty-three were shown to be spontaneously reduced and four to be recurrent subluxations of the ankle. Seven of twenty-four stable ankles had persistent disability for as long as five months when treated by injection and strapping.

2. By observing the course of the lateral ligaments and the effect on ankle stability of cutting them in various combinations, it is concluded that:

   A. The anterior talofibular ligament is the important component of the fibular collateral ligament of the ankle.

   B. Inversion films in severe ankle "sprains" should be taken with the foot in equinus, unless there is tenderness posterior to the fibula (which indicates injury to the posterior talofibular ligament). In this event the foot should be inverted with the ankle at 90 degrees.

3. Unstable ankles should be immobilized in walking plaster for about six weeks and should then be strapped with elastoplast for an additional two or three weeks.

NOTE: The author wishes to thank William J. Stewart, M.D., and Edward L. Compere, M.D., for their helpful suggestions and criticism.

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SOME OBSTETRICAL INJURIES TO THE LONG BONES

BY SPENCER T. SNEDECOR, M.D., AND HARRISON B. WILSON, M.D., HACKENSACK, NEW JERSEY

Trauma to the long bones of babies through the force of breech extraction is sufficiently common and serious to be of interest to the orthopaedic surgeon. The series of eleven cases reported here demonstrate a distinct orthopaedic entity with its causative mechanism, pathological changes, and course of recovery.

The long bones receive their greatest injury at the epiphyses, and by subperiosteal stripping of the tissues adjacent to them. The authors, an orthopaedic surgeon and an obstetrician, conceive the mechanism of this injury to be the strong manual pull and torsion strain exerted on the lower limbs when a baby is delivered breech first [8,10]. The extraction force is often exaggerated by the urgency of the delivery and is likely to be carried out in a consistent straight line, which necessarily causes severe torsion on the lower extremities, as the body of the baby must rotate 45 degrees to come through the birth canal. Under this strain the bone gives way at its weakest point; the epiphysis and the periosteum (and muscles) strip off down or up the diaphysis, as the case may be. The greatest periosteal separation occurs at the epiphysis. Within five to ten days a proliferative calcification takes place in the hemorrhage around the epiphyses or under the periosteum, and this becomes evident roentgenographically. An appreciation of the whole concept will help in avoiding the confusion in diagnosis and prognosis which the authors experienced with their first cases.

TABLE I

SUMMARY OF ELEVEN CASES

Babies born of primiparas	11
Breech presentation	5
Podalic version	6
Epiphyseal injuries	6
Periosteal stripping	7
Both epiphyseal injury and periosteal stripping	2
Sites of involvement	
Upper portion of humerus	1
Upper portion of femur	4
Lower portion of femur	7
Upper portion of tibia	1
Lower portion of tibia	2

A preliminary report of this phenomenon was made in 1935 [9]. Once the entity had been appreciated, careful observation uncovered other instances from time to time. During a period of twenty months, 160 babies who had had breech presentations were examined carefully. In fifty consecutive breech deliveries on the ward service of the Hackensack Hospital, the infants were x-rayed on the seventh day; and in three cases (6 per cent.) evidence of periosteal or epiphyseal hemorrhage was found. An equal number of other babies had painful limbs with obvious soft-tissue injury, but no roentgenographic evidence of bone disturbance. From this study it is apparent that this type of skeletal injury is relatively common in babies who have been forcefully extracted feet first, especially in the first-born (Table I).

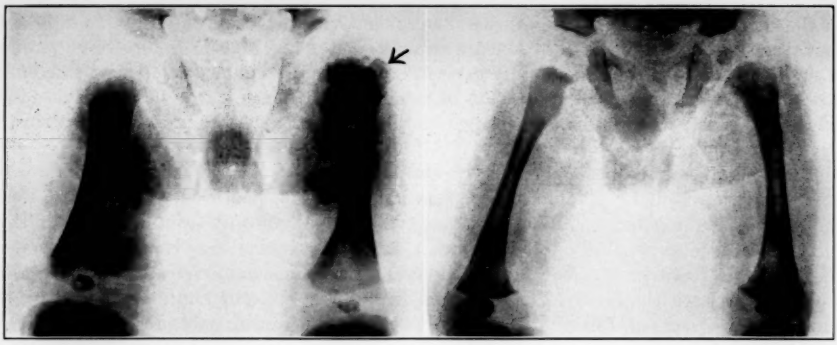

FIG. 1-A FIG. 1-B

Fig. 1-A: Case 1. Large deposit of calcium about capital epiphysis of femur, forty days after birth.
Fig. 1-B: Resolution three months later.

A review of the literature on birth injuries has disclosed frequent references to nerve palsies and obstetrical fractures. A few notations on epiphyseal trauma have been found, but no mention of periosteal stripping. Meier and Ruschenburg in Germany, Tavernier in France, Caritat and Peluffo in Uruguay, Rivarola in Argentina, and others have reported cases of obstetrical epiphyseal injuries. Scaglietti, in a summarizing report from Putti's clinic in 1938, told of such injuries to the capital epiphysis of the humerus. Other descriptions of separation of the lower epiphysis of the humerus, as well as of the upper and lower epiphyses of the femur, have been found in articles in the foreign literature. Two single case reports on epiphyseal injuries, recently published in the United States [1,3], show that this type of obstetrical trauma is coming to be recognized in this country. However, its occurrence as a relatively common complication of breech deliveries is worthy of special note, by both the obstetrician and the orthopaedic surgeon.

The clinical picture is quite typical. Tender swollen legs are observed the day after delivery. Whenever the limbs are moved, the child cries with pain. Roentgenograms

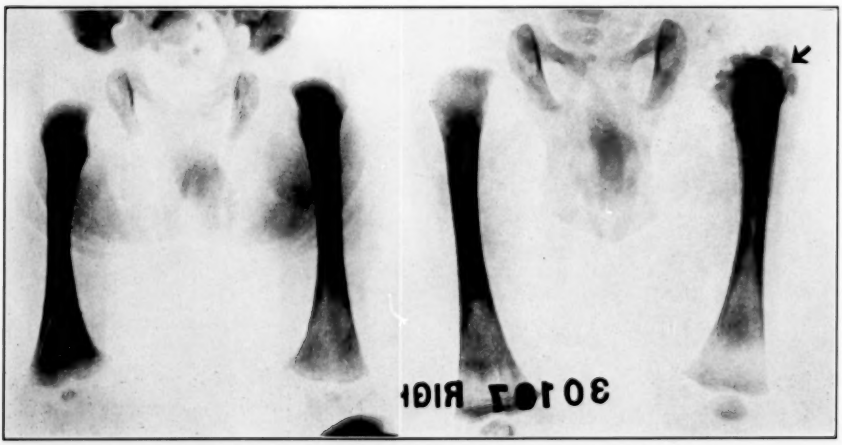

FIG. 2-A FIG. 2-B

Fig. 2-A: Case 2. Negative findings in roentgenogram taken five days after birth.
Fig. 2-B: Four weeks after birth, large mass is seen about upper femoral epiphysis, as well as some periosteal thickening.

on the second or third day have always been negative. In those infants with simple soft-tissue hemorrhage, the condition clears rapidly, but many of the babies have suffered enough trauma to have more lasting bone effects. Even as the acute physical discomfort subsides after a few days, a deposition of calcium takes place in the hemorrhagic nidus, and by the seventh day the roentgenographic picture illustrates the more severe periosteal and epiphyseal changes.

The significant roentgenographic characteristics of the lesion are dense shadows of calcification around the epiphysis, if separation or torsion has occurred there, and subperiosteally, if the muscles and periosteum have been pulled away from the bone. In three instances both sites became calcified (Cases 1, 8, and 11), indicating extensive involvement of both. The roentgenograms of other cases in the series demonstrate stripping along the shafts of both the femur and the tibia. In one instance the capital epiphysis of the humerus was involved, following a delivery with the arm in an extended position beside the head.

So far, eleven cases have been recorded in this series, but it seems certain that if babies with breech presentation, born of primiparas, are carefully checked with roent-

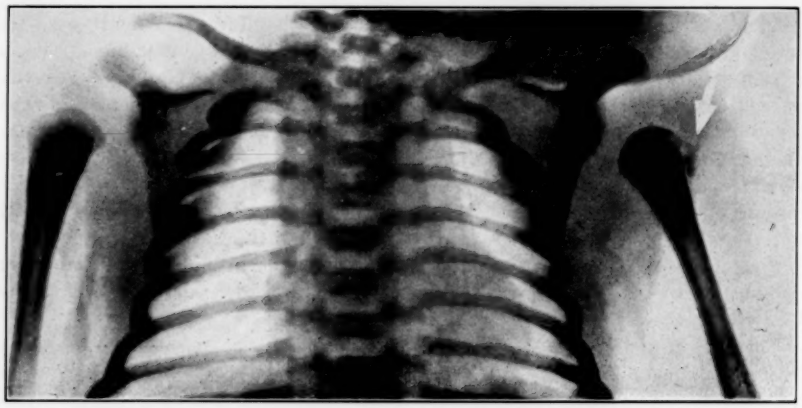

FIG. 3-A

Case 3. Calcium deposit at capital epiphysis of humerus nine days after birth.

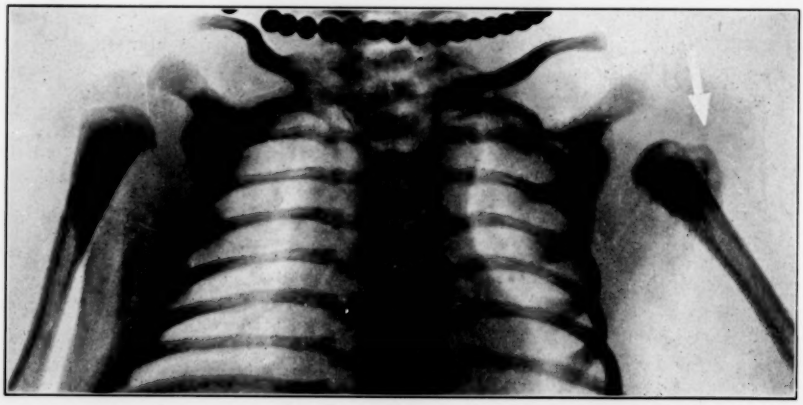

FIG. 3-B

Increased calcium five days later.

genograms taken on the seventh day, this injury will be found to be relatively common.

The prognosis following the injury has been uniformly good, with one exception. Within two or three weeks, all of the clinical symptoms disappear and the roentgenograms show a diminution in the periosteal thickening. Within three or four months, roentgenograms of the bone show practically complete resorption to a normal condition. In the one exception (Case 8), the lower epiphysis of the femur began to show distortion after four months. Later roentgenograms of this infant revealed a permanent bowing of the shaft for the first six years; an incidental fracture occurred when she fell from a crib at the age of one year. This child did not have a limp and was not handicapped in her activities, but it seemed clear that the lower femoral epiphysis had been permanently injured or displaced at birth.

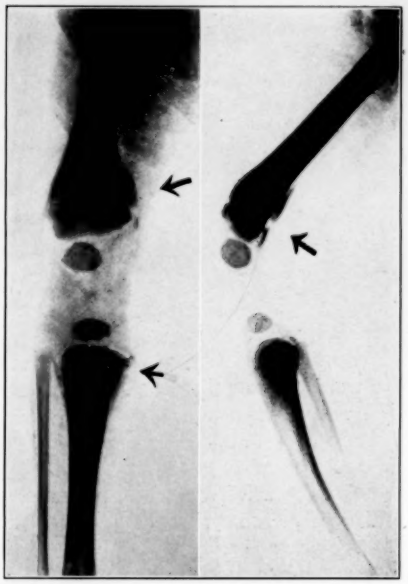

FIG. 4-A FIG. 4-B

Fig. 4-A and Fig. 4-B: Case 4. Periosteal calcification in right and left femora and upper portion of right tibia on the tenth day is shown. Some epiphyseal injury probably was present.

ABSTRACTS OF CASE HISTORIES

CASE 1. Baby M. was born of a primipara; delivery was by podalic version and breech extraction. Trouble with the lower extremity was apparently unnoticed until five weeks after birth. The limb was held in a flexed position and motion was painful. The first roentgenogram (Fig. 1-A), forty days after birth, showed a large mass of periosteal new-bone formation about the head of the femur. Three months later (Fig. 1-B) nearly complete resolution had occurred.

CASE 2. Baby A., who weighed six pounds and

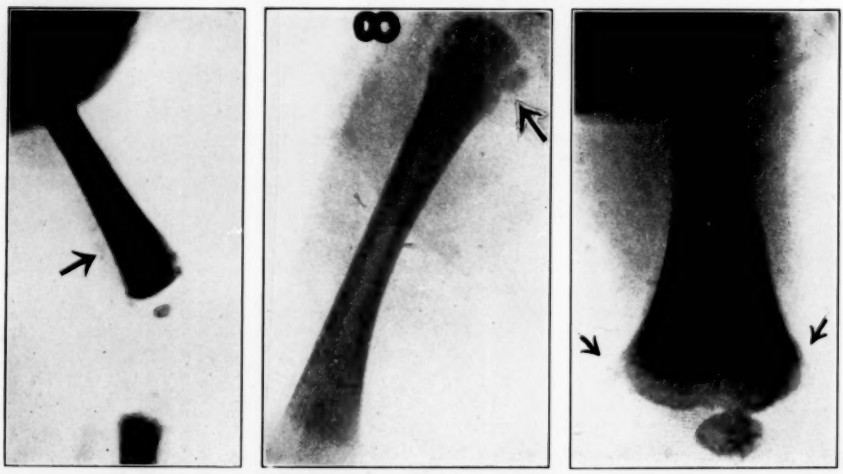

FIG. 5 FIG. 6 FIG. 7

Fig. 5: Case 5. Roentgenogram on eighth day shows periosteal stripping of lower half of femur.
Fig. 6: Case 6. Calcium deposit on medial aspect of upper portion of femur on seventh day.
Fig. 7: Case 7. Thickening of periosteum of lower portion of femur with periosteal horns, on ninth day.

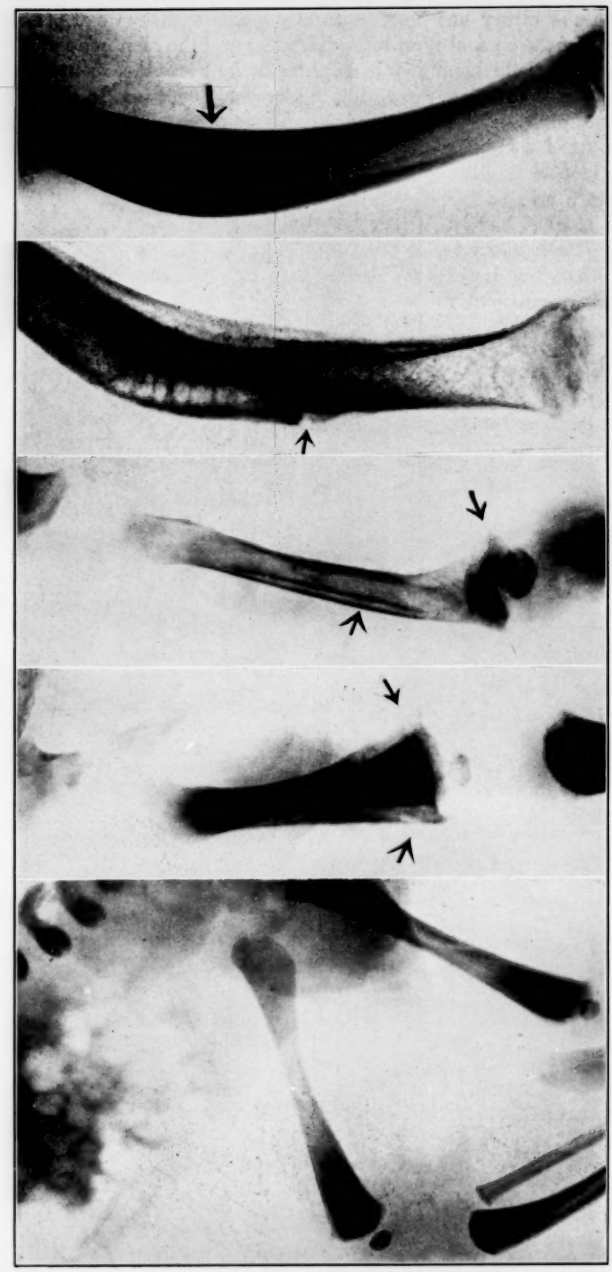

FIG. 8-A FIG. 8-B FIG. 8-C FIG. 8-D FIG. 8-E

Fig. 8-A: Case 8. Both femora negative on third day.
Fig. 8-B: Dense subperiosteal calcium deposit may be seen along lower half of femur and around epiphysis, on twelfth day.
Fig. 8-C: Resorption after four months, with beginning distortion of epiphysis.
Fig. 8-D: At one year, incidental fracture occurred through bowed femur. Fig. 8-E: Bowing of femur still present at age of six years.

twelve ounces, was born of a primipara; there was a difficult delivery by podalic version and breech extraction. The day after birth the infant's left lower extremity and foot were swollen, discolored, and painful on motion. The first roentgenogram (Fig. 2-A), five days after birth, was negative. Four weeks after birth (Fig. 2-B) a large amount of calcification was present around the head of the femur.

CASE 3. Baby H., who weighed eight pounds and fifteen ounces, was born of a primipara, with difficult delivery by podalic version and breech extraction. At delivery the left arm was in extension alongside the head. The injury to the left shoulder and arm was noticed immediately. The arm was limp and there was some wrist-drop. The first roentgenogram (Fig. 3-A), nine days after birth, showed periosteal proliferation around the upper epiphysis of the left humeral shaft. Five days later (Fig. 3-B) there was further calcification of the same area.

CASE 4. Baby M., who weighed eight pounds and five ounces, was born of a primipara, by breech presentation and delivery. The right lower extremity appeared swollen; the foot was bruised; and the infant held her limb in an awkward position. The left lower extremity was also bruised and appeared very painful. A roentgenogram, taken when the baby was two days old, was negative. When the child was ten days old (Figs. 4-A and 4-B) periosteal thickening was apparent in the lower half of the shafts of both femora and in the upper end of the right tibia.

CASE 5. Baby M., who weighed six pounds and eight ounces, was born of a primipara, by breech presentation and extraction. The left lower extremity appeared swollen from the knee to the hip, and was painful and tender to the touch. Roentgenograms on the eighth day (Fig. 5) showed periosteal stripping of the lower end of the femur.

CASE 6. Baby K. was born of a primipara, by breech presentation and extraction. The baby had bruises on both lower extremities. On the seventh day (Fig. 6) bone proliferation was seen at the proximal femoral epiphysis. Later roentgenograms showed complete absorption.

CASE 7. Baby W., who weighed six pounds and three and one-half ounces, was born by breech presentation and extraction. The baby held the lower extremities flexed in a peculiar manner; the right limb seemed swollen. Roentgenograms (Fig. 7), taken when the infant was nine days old, showed periosteal thickening and projections along the lower half of the left femur.

CASE 8. Baby S., who weighed six pounds and fifteen ounces, was born by difficult podalic version and breech extraction. The right lower extremity seemed partially paralyzed and motion caused pain. Three days after birth, a roentgenogram (Fig. 8-A) was negative. On the twelfth day (Fig. 8-B) extensive subperiosteal calcification was seen along the whole femoral shaft and around the lower epiphysis. After four months, roentgenograms (Fig. 8-C) showed resorption of the periosteal thickening, but early changes in the epiphysis. A fracture of the femur when the child was one year of age (Fig. 8-D) illustrated the marked anterior bowing. At the age of six years (Fig. 8-E) this bowing was still present.

CASE 9. Baby W. was born of a primipara, by breech presentation and extraction. No injury was noted at birth. After six weeks it was found that the baby kept his left lower extremity folded under the right and cried when his left limb was moved. Roentgenograms at six weeks showed marked proliferation around the head of the left femur and periosteal thickening down the shaft. Three weeks later a denser calcium deposit was visible.

CASE 10. Baby O. was born of a primipara, by breech presentation and extraction. Roentgenograms showed periosteal stripping and calcification at the lower ends of both the right femur and the right tibia.

CASE 11. Baby S. was born of a primipara; delivery was by podalic version and breech extraction. After birth the left foot appeared bruised. On the ninth day, roentgenograms showed ossifying periosteal hemorrhage of the lower third of the shafts of both the femur and the tibia.

CONCLUSIONS

1. Injuries to the long bones are relatively common complications of breech deliveries, especially in babies born to primiparas, and can be recognized as a definite entity.

2. Roentgenographic evidence of calcification in the hemorrhage is found on the fifth to seventh day.

3. These injuries follow a pattern of epiphyseal separation, periosteal stripping, and a combination of both.

4. According to the authors' concept, the mechanism of such injuries may be decreased by the use of less force, if possible, and by careful turning of the lower extremities to follow the rotation of the body during extraction.

5. The prognosis is relatively good for spontaneous recovery without specific treatment in most instances, but permanent epiphyseal growth changes may take place occasionally.

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DISCUSSION

Congenital Dysplasia of the Hip Joint

(Continued from page 372)

In reply to his question as to how I know there are many causes of intra-uterine dislocation, I should not have used the word *many*. I should have said *several*. When we examine children with dislocated hips, we occasionally find a child who has spina bifida and paralysis of the extremity. We know the mechanism of pathological paralytic dislocation. Occasionally we see a child who has clinical evidence of muscular dystrophy with degenerative fibrosis and contractures of muscles, as in myodystrophia foetalis or arthrogryposis multiplex congenita. We know that such contractures may displace the hip joint. If a child is born with one foot around the neck, with the knee hyperextended, and the hip joint in the position of flexion and adduction or of instability, it is only logical to assume that the hip was displaced because of the intra-uterine breech position. It is my opinion, however, that the great majority of congenital displacements of the hip are on the basis of genetic or biomechanical dysplasia of the hip joint, alone or in combination. Most displacements during infancy are subluxations and not dislocations. The terms preluxation and subluxation are synonymous. I believe that all patients with congenital dislocation of the hip joint secondary to congenital dysplasia have gradually passed through the phase of subluxation,—some during intra-uterine life, but the majority during early infancy, when dislocation could have been prevented by early recognition and treatment.

A MORTISED TRANSFACET BONE BLOCK FOR LUMBOSACRAL FUSION *

BY EARL D. McBRIDE, M.D., OKLAHOMA CITY, OKLAHOMA

For many years the orthopaedic surgeon has performed fusion as a dependable method of treating intractable low-back pain. Attention was sharply focused on the importance of the lumbosacral region through the discovery of the herniated intervertebral-disc syndrome by Mixter and Barr. It has now become necessary to re-evaluate the indications for lumbosacral fusion and to redetermine the end results.

The exceedingly prompt relief from acute pain obtained by operation for a herniated disc did not mask for long the fact that the pathological manifestations associated with herniation of the intervertebral disc are fundamentally structural deficiencies and only secondarily neurological entities. A more appropriate term would be "disc disease". Because the neurological phenomena are more obvious, a tendency exists to ascribe all low-back symptoms to the disc. Removal of the disc only has received too much credit, as stressed by Farrell and MacCracken. At present the literature contains many analyses of results of disc operations, with little or no consideration being given to the mechanics of associated structural disorders. It is the author's practice to expose freely and to investigate the posterior facets and foramina, bilaterally, in all disc operations. In 100 cases in which the facets and laminae on both sides were exposed at the time of disc operation, 46 per cent. showed mild structural deficiency and 35 per cent. showed marked pathological changes, such as telescoping of facets due to settling down of the intervertebral space, unexpected anomalies, senescent or osteo-arthritic changes, and obstructions along the course of the nerve roots. A large proportion of these abnormalities are missed if the roentgenogram alone is depended upon to reveal them.

The favorable end results in patients with disc lesions of long standing which have not been operated upon, and also in many cases in which operation has been done but not fusion, are probably due to stabilization from fibrous ankylosis. Slow, gradual narrowing of the intervertebral space is apt to follow removal of the disc. If this fibrous-tissue stabilization gives way, low-back pain may return. Bony fusion is the only way to counteract the predisposition of the lumbosacral structures toward progressive degenerative changes.

THE PRINCIPLE OF FUSION

Present Status of Opinion as to Value

Many variations and conflicting opinions exist concerning the advisability of fusion in the lumbosacral region. Briefly, the following assertions may be made:

1. Stabilization by fusion of the structurally affected lumbosacral joint is a sound, dependable procedure. It still may be said that a well-fused joint ceases to be painful. However, fusion is not a substitute for removal of the herniated disc or other source of nerve-root irritation.

2. Surgical intervention for the relief of pain due to posterior herniation of disc tissue has focused attention upon the frequency of a specific lesion in the lumbosacral region.

3. Whether or not to fuse in cases of herniation of the disc is debatable. Although enthusiasm for removal of the herniated disc has temporarily overshadowed the importance of structural disorders, fusion to prevent residual symptoms or relapse is justified to an extent greater than the neurological findings alone would indicate.

4. The numerous variations in technique of fusion operations in the lumbosacral region indicate dissatisfaction with results. Statistics have revealed a higher percentage of relapse with pseudarthrosis than is generally realized.

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1948.

5. Little new has been added to the technique of surgical fusion. Many methods have been described, but practically all are based upon the original method of Hibbs or Albee.

6. Interbody fusion by bone blocks in the intervertebral space, by either the abdominal or laminal approach, has been tried by Lane and Moore with some favorable results.

7. One new principle which has gradually gained recognition is that of distraction by propping apart the laminae or spinous processes to lessen foraminal impingement and to give immediate interlaminal support and stabilization.

8. Long periods of plaster-cast immobilization or bed confinement are being avoided.

9. A quick method of immobilization by transfixion screws in the facets, as recommended by King and others, is being tried. The reports are not convincing.

10. Metallic fixation by plating or wiring has been used in conjunction with bone transplants.

11. Iliac bone is rapidly replacing tibial bone, when transplants are used.

Recent Concept

In the light of present knowledge, surgical procedures in the lumbosacral region must be carried out with more specific intentions. Arthrodesis is not a substitute for removal of a herniated disc; but, if all local pathological factors are investigated, more fusions will be done supplemental to removal of a disc. More consideration is now given the taut stationary nerve roots. These nerve cables are threaded through passageways that might require bone decompression. If the smooth gliding surfaces of these nerve trunks are compressed or bound by adhesions, they will not respond to vertebral reactions from body shock, stress, or strain, even after fusion has been established. The great majority of end results following simple removal of the disc may be classified as good; but, in a joint defective enough to cause extrusion of a disc, further degenerative changes can develop. In this respect the situation is not unlike that found in inguinal hernia. One certainly would not remove the sac without carrying out the reparative procedure.

Improved Technique

Time has proved that successful fusion in the lumbosacral region depends greatly upon good engineering. The conventional bone-chip method of Hibbs or the bone-transplant method of Albee is more adaptable to the thoracic spine in children, for which these methods were originally recommended. Even though extremely heavy grafts and extensive bone chipping, of mutilating proportions in some cases, have been applied with many variations, absorption, followed by pseudarthrosis of the supposedly fused lumbar areas, has too often been the result. In a recent study, Cleveland, Bosworth, and Thompson have noted an incidence of pseudarthrosis as high as 20 per cent. in 647 fusions over a period of twenty years. This included all fusions extending from the third or fourth lumbar segment to the sacrum. In the lumbosacral joint, the incidence of pseudarthrosis was 3.4 per cent. This should be a stimulus for others to compare their end results and to seek improved methods.

The improvements needed in fusion of the lumbosacral area might be summarized as follows:

1. A more certain method of fusion, especially above the fifth lumbar body;

2. Development of a method providing earlier mobilization after operation;

3. Simplification of the technique of fusion and lessening of the time and risk when this procedure is done after a disc operation.

Principle of Interlaminal Distraction

The innovation of interlaminal distraction to decrease intraforaminal compression has proved valuable. It is usually accomplished by propping apart the spinous processes.

In many cases the collapse of the intervertebral space is found to have caused telescoping of the facets, to the extent that the inferior borders of the inferior articular processes rest on the adjacent laminae.

Williams first recognized the principle of distraction in his "conservative treatment" of lumbosacral disabilities, by maintaining a posture of flexion to correct the intervertebral subluxation and the narrowing of the foramina. Breck and Basom introduced the concept of maintaining fixed surgical distraction through the use of interspinous bone

FIG. 1-A

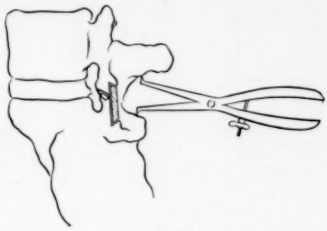

FIG. 1-B

The transfacet bone block, as a dovetailed graft, impacted under distraction into a rectangular mortise, extends from the laminae below to the facets above, to form an interlaminal supporting strut.
Fig. 1-A: Anteroposterior aspect.
Fig. 1-B: Lateral aspect.

blocks. Gibson devised the clothespin or fish-tail graft; Bosworth used a similar graft to lock the spinous processes in distraction. Moore has termed still another similar procedure the self-locking graft.

THE MORTISED TRANSFACET BONE BLOCK

It is frequently stated that fusion would be done more often after disc operations if a simpler method were available. The procedure described here is suggested with the aim of simplicity.

The most strategic point for elimination of intervertebral motion is at the facet articulations, as stressed by Meyerding. Their surfaces are comparatively large and the center of gravity is more nearly at this point. The articular processes are strong and sturdy enough to provide an excavated bed and abutments for the firm implantation of a substantial block of bone. When accurately countersunk across the facets (Figs. 1-A and 1-B), such a graft will render immediate support and stabilization, and will eventually produce an interlocking bony fusion. An operative technique devised for such a mechanical objective has been employed in 135 cases with gratifying results.

Technique

The patient lies prone on an especially devised convex frame (Fig. 3); two padded saddle bars support each side of the pelvis, leaving the abdomen free from pressure. The spinous processes and laminae on both sides are thoroughly denuded and the soft tissues are widely retracted, to permit free visualization of the facet articulations of the involved region.

Attention is directed to a small but definite anatomical structure, not described in the anatomy texts, consisting of a ball of fat that fills the interlaminal fossa. It borders the ligamentum flavum medially and is attached laterally to the fascia over the facet, to

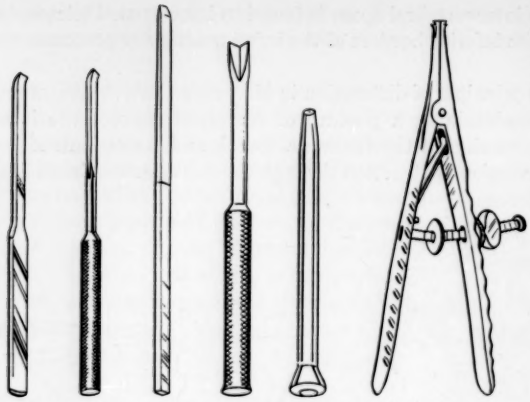

FIG. 2

Special instruments used in accurately countersinking the transfacet bone block.

receive a small terminal artery and nerve from the lateral margin of the superior articular process of the vertebra below. No doubt this is the cause of the troublesome bleeding which Hibbs originally mentioned in describing his fusion operation. It is of advantage to coagulate this vessel and to remove the entire fat pad before removal of the ligamentum flavum.

If the disc is to be explored, this part of the operation is completed prior to the fusion. Whether the disc operation is done or not, the ligamentum flavum and all fibrous tissue are thoroughly cleaned from the bone. Spreaders are then applied between the spinous processes to correct any telescoping of the facets that may have occurred from collapse of the intervertebral space.

A rectangular excavation is made lengthwise in the articular processes, crossing the facets above and extending into the laminae below. The excavation should be about one-fourth to three-eighths of an inch wide, one-eighth to three-sixteenths of an inch deep, and from one-half to three-quarters of an inch in length. The upper end should be so located as to include about equal parts of the articular processes. A right-angled osteotome, with each blade one-quarter of an inch wide, is used to make square corners, although an ordinary thin osteotome, one-quarter-inch wide, may be employed. Starting at a point about three-sixteenths to one-quarter of an inch above the inferior border of the facets, the first cut is made into the articular processes until the osteotome extends through the facet of the inferior articular process of the vertebra above. The lateral margins are then cut and accurately squared. The upper end of the excavation is undermined and all cartilage surfaces are removed. Care should be used not to break the outer ledge of the superior articular process of the lower lumbar vertebrae. Likewise, it is important to have a substantial medial wall to the excavation; otherwise the graft will shift sidewise.

FIG. 3

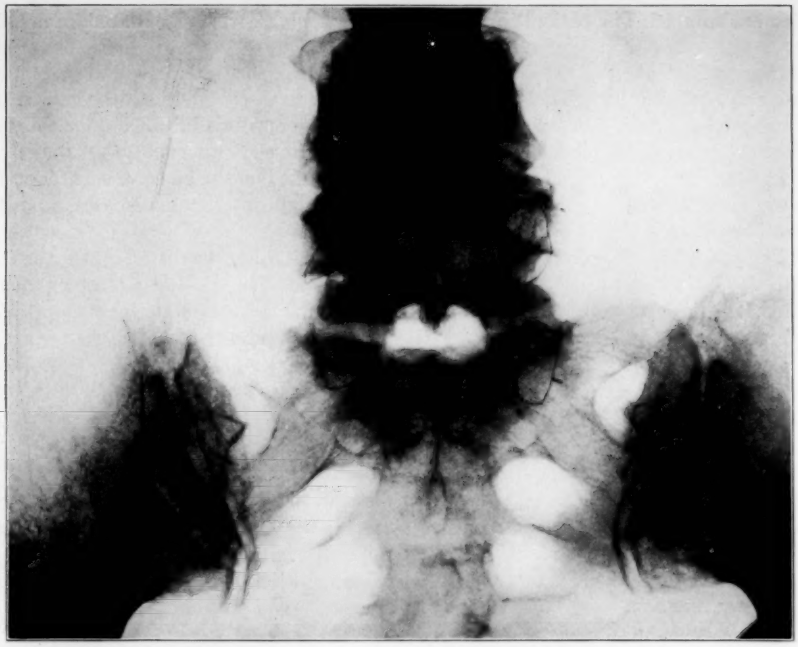

FIG. 4

Tantalum wire used to demonstrate roentgenographically the location of the bone blocks.

The lower end of the excavation is located on the lamina below, about one-half inch lateral to the base of the spinous process. The depth may be from one-eighth to three-sixteenths of an inch, but caution should be used not to penetrate the wall of the neural canal. The floor of the excavation, which consists largely of the articular facet of the superior process of the lower vertebra, is leveled by a thin, quarter-inch osteotome, slightly curved on the tip. The upper and lower ends of the excavation are undercut to the extent that a beveled bone block, about three-sixteenths of an inch thick, can be countersunk in dovetailed fashion to lock the graft into the depth of the cavity as the interlaminal spreaders are removed. Additional bone chips may be wedged about the articulations, or other additions may be made as desired. The bone-block grafts are taken preferably from the spinous processes; each process will furnish material for two blocks. The prominence at the posterior spine of the ilium may be used if thicker, heavier bone is desired. Two qualifications are necessary for the bone blocks:

1. They must be long enough to be wedged firmly in place by the driving force of a carpenter's punch.
2. They must be strong enough to withstand the pressure when the distraction force between the vertebrae is released.

To wedge the graft into the excavation, the interlaminal spreaders are applied. The upper end of the block is first pressed into place. Then with a punch, the other end is tapped firmly and impacted into position. The transfacet bone blocks are wedged into place on each side before the distraction produced by the spreaders is removed or changed. If the graft is not impacted firmly and does not lock in place, it should be removed and made to fit more accurately. When the spreaders have been removed, the grafts are tested for firm impaction and the wound is closed, after the operator has made certain that all blood

oozing has stopped. The patient is placed in bed on his back with no external immobilization.

In spondylolisthesis, the cartilaginous material in the pars interarticularis is removed thoroughly, and the bone block is made long enough to insert well into the cavity. The laminae are left intact. Immediate immobilization is the result. Additional bone chips and grafts may be used if further assurance of fusion is necessary.

In four cases of scoliosis, the blocks have been applied on the concave side for correction of the curve. With one-quarter inch of spread on eight interlaminal spaces, a positive correction of two inches is obtained.

The patient is allowed bathroom privileges on the tenth or twelfth day. On the fourteenth day, a model is made for a low-back corset type of brace, and a plaster jacket is applied. This jacket is exchanged for the brace about the fortieth day after the operation, when light work is permitted. Hard manual labor, such as riding a tractor or heavy lifting, is not permitted for four months. A number of patients have disobeyed this rule, however, with no apparent harm.

RESULTS

In the 135 cases in which fusion was achieved by this method, there have been no deaths or serious complications. Abdominal distress, mild or severe, has occurred occasionally, and catheterization has been necessary for the first day or two after operation in about 20 per cent. of the cases. Most of these complications occurred when the fourth and fifth lumbar interspaces, as well as the lumbosacral joints, were fused. Most patients

FIG. 5-A

FIG. 5-B

Biplane roentgenograms following transfacet bone-block fusion of the fourth and fifth lumbar vertebrae.

Fig. 5-A: Forced flexion.

Fig. 5-B: Forced extension.

FIG. 5-D
Forced lateral bending to the left.

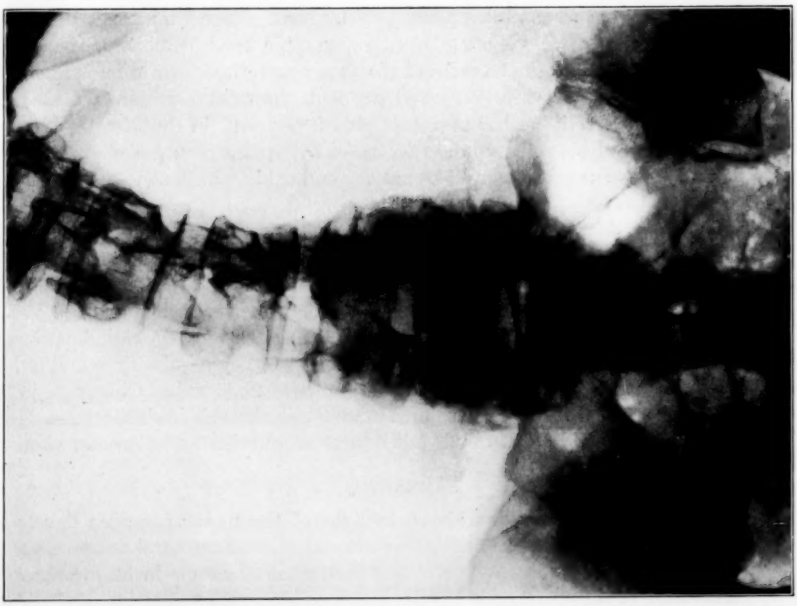

FIG. 5-C
Forced lateral bending to the right.

TABLE I

EVIDENCE OF PSEUDARTHROSIS IN FORTY-ONE CASES, AS DETERMINED BY ROENTGENOGRAMS IN FORCED LATERAL AND FORWARD BENDING, TAKEN AFTER SIX MONTHS TO TWO YEARS

Diagnosis	No. of Cases	Area Fused		Cases Showing Possible Pseudarthrosis by X-ray	
		Fifth Lumbar and First Sacral Only	Fourth and Fifth Lumbar and First Sacral	Fifth Lumbar and First Sacral	Fourth and Fifth Lumbar
Herniated disc	31	15	16	1	4
Spondylolisthesis	3	0	3	0	0
Collapsed narrow joint	2	2	0	0	0
Other anomaly	2	0	2	0	0
Osteo-arthritis	3	0	3	0	0
Totals	41	17	24	1	4

experience a sense of stability by the third or fourth day. Undue pain following operation is rare; but, when it does occur, it is usually due to a hematoma. In no case could it be determined that the nerve was affected by the excavation into the articular processes or by the trauma of inserting the bone block.

In one case, recurrence of symptoms was sufficiently severe to justify reoperation. The lower margins of the bone block were fused; the upper margins were not. Various methods have been tried to demonstrate more clearly whether or not fusion takes place. Tantalum wire was passed tightly around the edges of the bone block in a few cases, and the ends were fastened by twisting. The wire localized the bone block in the postoperative roentgenograms (Fig. 4). Otherwise the graft is not discernible, even in an oblique view.

Seventy-four cases were followed by roentgenograms taken with the patient in forced anteroposterior bending, a method described by Gianturco. Since Cleveland, Bosworth, and Thompson described their "biplane roentgenographic test", follow-up roentgenograms have been taken in both the lateral and the anteroposterior views of forced bending (Figs. 5-A to 5-D). In the first series, only 11.1 per cent. showed the presence of pseudarthrosis in the fourth and fifth lumbar segments, and 2 per cent. in the fifth lumbar and first sacral region. An analysis of forty-one cases tested by biplane roentgenograms is found in Table I. These roentgenograms were taken at the end of six months and after one year or more.

Pseudarthrosis, as demonstrated by biplane roentgenograms, was found in four cases with fusion of the fourth and fifth lumbar vertebrae, while the same roentgenographic technique seemed to have indicated that solid stabilization occurred in all instances in the lumbosacral joint. Fusion has depended almost solely upon the wedged bone blocks; occasionally a few bone chips were added about the facets. There are no contra-indications to any additional measures for reassurance of fusion; however, they require time and induce greater risk. It is thought that the simple bone-block procedure is entirely adequate in the lumbosacral joint. Fusion of the fourth and fifth lumbar vertebrae seems less certain. Here, additional bone chips packed about the denuded facet articulations offer greater security.

SUMMARY

Lumbosacral fusion must be considered in light of the newer concepts developed through surgical treatment of herniated intervertebral discs. Structural faults must be re-evaluated. Stabilization by fusion is still the treatment of choice in lumbosacral instability, irrespective of the spectacular results obtained after removal of the disc without

fusion. Pseudarthrosis, especially of the fourth and fifth lumbar segments, has been found frequently after the regular types of fusion, and a special technique is necessary.

The technique described for accurately impacting a mortised transfacet bone block under interlaminal distraction has the following advantages:

1. The period of confinement in bed is increased very little over that required for simple removal of a herniated disc.

2. The fusion technique adds thirty minutes or less to the time involved in removing a herniated disc.

3. There is a minimum amount of mutilation of the spinal structures.

4. The articular facets are fused, which is of mechanical advantage.

5. The bone block rigidly stabilizes interlaminal motion, immediately after being countersunk into position.

6. Extension of the spine after operation locks the bone grafts firmly into position.

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DISCUSSION

DR. DAVID M. BOSWORTH, NEW YORK, N. Y.: In June 1947, Dr. Cleveland, Dr. Thompson, and I reported the incidence of pseudarthrosis in our series of lumbosacral spine fusions. Comparable reports by other authors are possible only through the presentation of a similar number of cases and similar roentgenographic criteria of fusion (superimposable roentgenograms taken at the extremes of bending in two planes). It does not avail to emphasize the high incidence of pseudarthrosis in the past as a standard of comparison for a new technique of fusion, unless comparable evidence of fusion and pseudarthrosis is presented in support of the new technique.

The development of pseudarthrosis after lumbosacral fusion has not been discouraging. Some pseudarthroses are always likely to occur, but the percentage has gradually decreased over the years as new surgical means have been employed, based on better understanding of the basic factors of bone growth and repair. Of some 650 cases of lumbosacral fusion reported by us, about 3 per cent. of pseudarthrosis developed when

(*Continued on page 399*)

ASPECTS OF PHYSICAL RECONDITIONING *

BY MARCUS J. STEWART, M.D., MEMPHIS, TENNESSEE

Conservation of manpower and the gainful existence of the individual following orthopaedic injuries and disease are attained not so much by the restoration of function, as by continually preserving function. Thus, in the initial treatment of fractures, reduction of the bone fragments should not be paramount, but rather the decision as to the most rapid method of restoring the whole individual to a functioning, economically solvent capacity. Surgical repair and treatment should be based on a program which will adequately immobilize the injured part, and at the same time maintain good tissue turgor and a properly functioning vascular tree, and allow early active exercise. In operative cases, it is as much the surgeon's responsibility to impress upon the patient the importance of postoperative care and proper muscle re-education as it is to employ good surgical technique. Each patient who faces more than a few days of convalescence should be given a detailed schedule of active rehabilitation,—especially a program of remedial exercises.

MILITARY REHABILITATION

The need for conservation of manpower in the British Army during World War I gave birth to the first large-scale systematic program of rehabilitation, under the guidance of a physical-training instructor. This plan thrived under the direction of Sir Robert Jones until the cessation of hostilities; it was then abandoned for twenty years. However, at the beginning of World War II, the system was quickly revived and inaugurated in the British Army under the guidance of the late General Rowley Bristow, and in the Royal Air Force by Sir Reginald Watson-Jones and Air Commodore Osmond-Clarke. The manpower salvaged by these rehabilitation centers and convalescent depots was, no doubt, one of the big factors which enabled the British to stand against seemingly insurmountable odds, and to stem the initial tide of the War.

A physical-training corps was established for the British Army at Aldershot, England, in 1680, and has since then functioned continuously. From this corps, physical-training instructors were assigned to the various hospital units of the Army and Royal Air Force, and, under close supervision and direction by the medical staff, they carried out their superb work.

The British Convalescent Depot is the stepping stone from hospital back to duty, and is the antecedent of what has been established in the United States Army Medical Corps as a Convalescent Center. The British Rehabilitation Center was formed for the conditioning of under-par inductees,—the men who, in the United States, would be classed as 4-F or placed on limited duty. For example, one of the British Centers, early in 1942, had received and processed about 5,000 of these inductees. The system of classification upon induction was to place a man in one of seven categories of physical fitness. Of these 5,000 men undergoing a planned program of physical conditioning, postural exercises, and training, the British were able to raise the category of physical fitness in 85 per cent.; and, of these, 77 per cent. were placed in A-1 classification.

In the United States Army in the European Theater of Operations, the dire need for a stepping stone from hospital to duty was evident. The initial 150-bed unit, which was established late in 1942, had expanded by May 1945 to include a program of 13,000 beds for convalescent reconditioning. This program alone returned over 60,000 men to full duty. During the last year of military operations in the European Theater, 15 to 20 per cent. of the total bed capacity was devoted to advanced reconditioning. Under this program, about

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1948.

90 per cent. of the patients were returned to duty; of the 90 per cent., 83.6 per cent. were battle casualties.

For example, in a series of men with back injuries, 415 patients were treated and studied. The injuries included 121 fractures of the spine, ranging in severity from forty-one patients with fractures of the transverse processes to twenty-seven with compression fractures of the lumbar bodies. These 121 patients spent an average of 117.3 days in the hospital. In the total series are included such cases as arthritis of the sacro-iliac joints, spondylolisthesis, incomplete sacralization of the last lumbar segment, myofascitis, and others. All of these patients were placed on a program of specific remedial back exercises, carried out by physical-training instructors under the direction of orthopaedic surgeons. The 415 patients spent an average of 101 days from the date of injury until return to duty. Of the total group, 92.3 per cent. returned to duty in the European Theater of Operations; of these, 57.8 per cent. returned to full military duty, and 7.7 per cent. were transferred to other hospitals or returned to the Zone of the Interior.

Of the patients with chest injury, 418 were given a program of special rehabilitation and study. This group included sixty-nine cases of compound gunshot wounds penetrating the pleural cavity and lungs; 110 cases of hemothorax resulting from severe contusion and other injuries; twenty-three cases of pneumothorax; and various other types of chest injury. All of these patients spent an average of 112 days in the hospital under active treatment and a planned program of rehabilitation. Of the group, 86.6 per cent. returned to duty in the European Theater of Operations, 4.5 per cent. were returned to the Zone of the Interior, and 8.9 per cent. were referred for more definite thoracic surgery.

Three hundred and nine patients with fracture of the carpal navicular were treated by plaster immobilization alone and returned to duty. The hand and wrist were held in midulnar and radial deviation, and dorsiflexion of about 15 degrees, with the thumb and fingers in the grasping position. This position of the wrist was maintained by plaster, which extended from one inch distal to the elbow to the proximal palmar crease, and as far as the base of the thumb nail. These men were given a specific routine of remedial exercises for the affected hand, as well as general physical exercises.

After continual immobilization of two to fourteen months (an average of 4.2 months, depending to a great extent upon the location of the fracture), the restoration of function required an average of only three and one-half weeks before full, normal motion and strength were present in the hand and wrist.

These results in army rehabilitation were not obtained because of the virtue of any given series or specific type of exercises, but because exercises were enthusiastically taught and religiously executed in a sedulous and progressive manner.

INDUSTRIAL REHABILITATION

A great deal has been accomplished by reconditioning in the Armed Forces and in the Veterans Administration. Now, industry is rapidly developing programs of a similar nature. In Britain, industrial cooperatives, unions, and insurance companies are reclaiming untold manpower. In some American cities, insurance companies and industrial organizations are perfecting excellent programs. Many leading medical colleges and universities have well-advanced courses in programs of reconditioning. All industries and insurance companies are becoming aware of the value of reconditioning programs which include part-time employment. Partial pay for work and accomplishment helps to elevate the individual financially and mentally from the degrading compensation dole.

REHABILITATION IN PRIVATE PRACTICE

The private patients of today, compared with those from the military service or industry, are, in many instances, suffering from the lack of proper and thorough reconditioning. Many doctors feel that they must have an elaborate therapeutic gymnasium before

they can offer their patients good reconditioning. This is a completely erroneous idea. As Watson-Jones points out, rehabilitation can be efficiently practised in a barn with no apparatus or gadgets.

It has been our experience that it is best to develop, first, improvement in tone, coordination, and control by muscle tensing. Then, non-weight-bearing, weight-resisting exercises should be started, using one, two, five, and ten pounds of resistance in a progressive manner until strength, endurance, and agility return. If more power is desired, heavier weight resistance is indicated, as advocated by DeLorme. In most patients, the range of motion will return in direct proportion to the improvement of the musculature controlling that joint.

At the Campbell Clinic, remarkable improvement has been noted in many patients with various injuries, after a rather strict regimen of active muscle-building exercises had been instituted. Improvement has been most outstanding in patients with back injuries, both chronic and recent; the results in cases of knee injury have also been of striking interest. Three representative case reports are cited:

CASE 1. Mrs. E. G., fifty-three years old, fell fifteen feet when a stairway banister gave way and she plunged to the floor. She sustained a compression fracture of the ninth thoracic and second lumbar vertebrae; there were no neurological changes. Under general anaesthesia, the fracture fragments were hyperextended, reduced, and maintained in a plaster body jacket. After three days, she was placed on a program of exercises for the lower extremities and arms. On the tenth day, she commenced back exercises in the plaster jacket. At the end of three weeks, she could, by hyperextension, lift her head, shoulders, and the upper part of the cast off the bed forty-five times at one exercise period. At the end of two and one-half months, the plaster was removed and the musculature of the back was found to be in excellent condition. With the temporary aid of a brace, she returned to her job and has worked without interruption or complaint.

CASE 2. Mrs. E. R., aged thirty-eight, related a history of pain in her back for ten years. Since onset, there had been periods of remission and exacerbation, but she had never been entirely free from pain and disability. Symptoms were located in the lumbar region, but there was no sciatic radiation. Examination revealed an increased prominence of the spinous processes of the lower thoracic and upper lumbar vertebrae, with accentuation of the lumbar curve and a general increase in the thoracic kyphosis. There was very little muscle spasm until motion was attempted; movement produced immediate fixation in flexion and extension, but lateral bending was possible to 50 per cent. of normal. Pressure on the lumbosacral joint was painful. All leg signs were essentially normal; patellar and Achilles reflexes were normal. Roentgenograms revealed an increase in the lumbar and thoracic curves, with osteo-arthritic changes, Schmorl's nodules, and evidence of old juvenile osteochondritis.

The patient was given instructions in conservative care of her back, and was fitted with a low-back steel brace. She did not wear her brace or follow instructions, but returned in one month with symptoms more severe than before. She was admitted to the Hospital and was placed on a firm bed; adhesive traction was applied to both lower extremities, and heat treatments with gentle relaxing massage were given to the lower back. After four days, back exercises were started. She was discharged nine days later with explicit instructions concerning her exercise program. After six weeks, she was free from pain and resumed normal activity.

The patient was last seen ten months later and the following note was recorded: "Patient states that she is remarkably improved and has had no pain in her back since beginning the series of exercises. There is no muscle spasm, pain, or tenderness at this time. Range of motion is essentially normal in all directions. All special leg signs and tests are normal. She was instructed at this time in more vigorous exercises, and advised to continue with the entire series."

CASE 3. F. O., a male, aged fifty, gave the following history: In December 1946, he fell and struck his knee on a concrete step. Pain was not severe at the time of injury, and he required only palliative treatment. Examinations for bone, cartilage, or ligament injury were all negative. However, effusion, mild pain, and periarticular reaction developed over a period of weeks, and the knee became weak and unstable. He had been seen in several nationally known clinics, and had been told that he should have an exploratory arthrotomy of the knee, but he had refused. The condition of the knee grew worse; he became incapacitated and could not continue his work even with the aid of a brace.

He was first seen by us in September 1947; examination revealed moderate effusion of the joint, no tenderness or ligamentous instability, but marked general laxity. The musculature of the thigh was very weak, and marked atrophy was present. He was unable to extend the knee more than three times against gravity. Roentgenograms of the knee were negative except for early, mild, hypertrophic arthritic changes.

A diagnosis was made of chronic traumatic synovitis with early arthritis. The patient was placed on weight-resisting exercises for the quadriceps and hamstrings. At the end of one week, tone in the muscles showed excellent improvement. In six weeks, the knee had become asymptomatic. A good musculature of the entire extremity had developed; there was no effusion; the patient could lift ten pounds of weight seventy-five times with the quadriceps, and could climb steps with ease. At this time, he returned to full employment.

Jostes has recently pointed out the importance of establishing and maintaining good body mechanics with correct posture, not for a given exercise period, but for twenty-four hours a day. He stated that good posture is found in "those emanating good health, confidence, courage, and personal cleanliness. Good posture is rarely associated with cringing, withdrawn characters, with slow-moving, weak, timid and dull individuals." He also stated: "Correct posture is, therefore, a dynamic concept involving proper use of all muscles and indirectly proper position of internal viscerae".

The two most essential steps in rehabilitation are, first, the proper instituting of early active exercises, and, second, a conscientious and enthusiastic effort on the part of the doctor to impress the patient with the importance and necessity of carrying out such a program. Unless the proper mental attitude and desire for recovery are well established in the patient, reconditioning plans will be for naught. Where possible, exercises for the involved part and deep breathing should be taught prior to surgery. After surgery or injury, exercises should be commenced as soon as the patient recovers from the anaesthesia, provided there are no symptoms of shock, cardiac failure, or other acute complications. Immediately after arthrotomy of the knee or nailing of a fracture of the neck of the femur, for example, exercises of the arms and unaffected lower extremity, with deep breathing, should be started. Muscle-tensing exercises should be started on the affected extremity on the first postoperative day. The patient may be allowed to sit up at this time, but ambulation is not necessary or indicated.

Recumbency and lack of active exercise are conducive to a multitude of ills,—poor circulation, embolism, pulmonary and cardiac congestion, osteoporosis, and poor callus. The metabolites of combustion in the tissues of the body, especially in the muscles, undoubtedly play a more important part in the proper healing and recovery of tissue than has ever been explained. Dock states: "Thrombosis is the most frequently fatal sequal of complete bed rest, and the common cause of serious pulmonary complications. *Hypostatic* bronchopneumonia is second in frequency, and is a more complex problem in which recumbency plays a contributing role of great importance." It is also known that nitrogen balance can seldom be established, even with a high-protein diet, in the face of inactivity and recumbency. Zava reported 6,000 patients operated upon, who were allowed out of bed on the first postoperative day, without a single case of embolism. Leithauser is given much credit for furthering early ambulation. In 1943, he reported 900 cases in which the patients were allowed out of bed in an average of 1.3 days, and out of the hospital in four days. There were no cases of pulmonary or other emboli. He stated that a common explanation for the presence of complications is: "He got up too soon; but in reality, he got up too late". A large proportion of the fatal cases of embolism occur about the thirteenth day, or soon after the patient rises from a prolonged stay in the recumbent position.

Kümmell advocated getting patients out of bed on the first postoperative day, following celiotomy. Pool stated in 1913 that he had had his own appendix removed and had commenced exercise on the third postoperative day; he had begun early ambulation with excellent results. He stated: "All movements of the limbs should be performed with voluntary muscular resistance". Pool continued, for the rest of his life, to be a strong advocate of early active exercise.

In 1930, Mermingas reported allowing his patients to walk from the operating room after undergoing appendectomies under local anaesthesia. Blain stated in 1946: "At our Clinic in the past three years, no patient getting out of bed within one or two days following operation has succumbed to pulmonary embolism, evisceration or other serious compli-

cation. We have found that the distressing sequelae following operation, such as gas pains, constipation, weakness and urinary retention, have been eliminated in these patients. . . . Opiates, sedatives, laxatives, stomach intubations and bladder catheterizations have all but disappeared from our post-operative order sheets for the majority of surgical patients."

Ghormley pointed out that, although the pathological physiology of atrophy is not understood, it occurs from prolonged rest; and there is not only bone involvement, but involvement of all the soft tissues as well. Normally, tendon sheaths and fasciae are smooth, glistening, and present a gliding surface, but in areas which have been immobilized for a period of time, the operating surgeon finds that the muscle surfaces are dull and anaemic, and that the development of adhesions is noticeable.

Some of Dr. Chandler's patients, who had had fusions of the lumbosacral joint, were recently seen by the author; they were sitting up in bed on the third postoperative day, and were out of bed on the fifth day, leaving the hospital on the ninth or tenth day.

Entirely too much time and effort have been spent in trying to convey the importance of a specific type or series of exercises. The paramount objective should be to teach the patient the importance of systematic and regular exercises. The initial step is the responsibility of the surgeon for the orientation of the patient, not only with the procedure, but also with the objective and goal.

The ideal stepping stones to physical reconditioning of the patient are:

1. An enthusiastic desire on the part of the patient and the doctor to attain and maintain the best possible function of the affected part and of the whole body;

2. The acceptance of a program of early, active non-weight-bearing and weight-resisting exercises, religiously executed;

3. Intelligent and systematic deep breathing, with conscientious maintenance of good posture;

4. The application of heat, massage, and special apparatus in selected cases.

The doctor and the physical instructor must gain the patient's complete confidence and cooperation; the keynotes should be patience, sincerity, enthusiasm, and optimism. The patient should be taught three important phases of muscle rehabilitation: (1) contracting, (2) sustained contracture, and (3) complete relaxation. The objective should be what is commonly referred to as *dynamic* physical reconditioning, or dealing with the specific therapeutic need of the individual, in contrast to physical reconditioning, which refers to general calisthenics.

Strickland and Morgan quoted McCloy as stating, in an address on reconditioning delivered in 1944: "It has been found by experimentation in the physiological laboratory that an individual capable of enduring 18,000 kilogram-meters of work in a given time without rest, after two weeks' inactivity, in which time he is walking around but doing no other exercise, will retrogress until he has the ability to do only 8,000 kilogram-meters of work in that time".

There is no longer any question as to the importance or practical value of early active exercises, early ambulation, and weight-resisting exercises. There is, however, a great divergence of opinion as to what type of activity is best and how it can be executed most effectively. The need for an investigation of these questions is evident, in order that a yardstick or practical guide to reconditioning and early ambulation for orthopaedic injuries and diseases may be formulated.

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DISCUSSION

TRANSFACET BONE BLOCK FOR LUMBOSACRAL FUSION

(*Continued from page 393*)

the fifth lumbar interval alone was bridged. The percentage rose roughly to 17 when the fourth and fifth lumbar intervals were crossed. Later cases in the series showed a lowering of this percentage to about 12 when the last two lumbar intervals were spanned. The development of surgical technique has made a considerable difference in the percentage of successes, but mainly through the use of more finely divided graft material, material of more cancellous nature, and through the use of procedures which better stabilize the region.

Among the 650 patients operated upon, approximately 1,300 spinal intervals were crossed with an incidence of pseudarthrosis of 12 per cent. Since 1940, all results have been checked by superimposable roentgenograms and, although our technique has improved and more solid ankyloses have been obtained, the reportable pseudarthrosis rate has risen. This is directly attributable to the better knowledge gained by the use of such roentgenograms; in the future, no results should be reported which are not based upon them. Curettage of the facet area, followed by graft implantation, was not carried out in our series. Reports on a similar series by Dr. Alan DeForest Smith, in which the facet area was curetted and grafted, showed essentially the same percentage of pseudarthrosis. Hence we prefer to leave the facets intact, to provide a normal stabilizing mechanism in case pseudarthrosis develops.

It would have been somewhat difficult to use Dr. McBride's technique in many of the spines we have seen. Distraction he undoubtedly can obtain, but permanent stability of the grafts (beyond two or three weeks) might not be present routinely. I believe that lately he has been using considerable supporting graft material, after placing his blocks in the facet region to produce distraction. His ideas are logical and the results may be good.

Such future advance as may occur in the art of spine fusion at the lumbosacral angle will probably not be the result of surgical techniques. Further development of knowledge of the factors favoring bone growth and repair, both local and general, will undoubtedly help to reduce the percentage of pseudarthrosis.

PSEUDARTHROSIS FOLLOWING SPINE FUSION *

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In 1911, Hibbs[33] and Albee[2] published descriptions of their respective operations for fusion of the spine. Since then, improvements and modifications of the original techniques, and additional types of operations [5, 9, 10, 11, 19, 24, 25, 26, 29, 32, 46, 47, 49, 52, 56, 60] have been presented, as well as the application of these new surgical procedures in the treatment of a wide variety of diseases and deformities of the spine [20, 34, 35, 39]. The choice of the procedure for spine fusion in the treatment of these various clinical conditions has occasioned much debate since the first descriptions were published. The value of spine fusion in the treatment of tuberculosis of the spine [1, 8, 13, 16, 17, 18, 21, 30, 31, 41, 44, 48, 50, 57], of scoliosis [14, 38, 45, 54], and of instability in the lumbosacral spine [15, 22, 27, 39, 42, 51, 53], especially following disc removal [6, 7, 23, 28, 55], has been questioned. From its widespread use in orthopaedic practice today [3, 4, 16, 17, 23, 27, 51, 55, 58], it is evident that some success has followed this operation as applied in the past.

It is not the purpose of this paper to enter into a discussion of the indications for and the value of spine fusion. The authors are concerned with the basic question involved: Does this procedure result in fusion of the spine? By fusion, the authors mean the fixation of the spine by a continuous column of bone which allows no motion in any plane of the body, throughout the vertebral segments involved. It has never been completely ascertained [9, 12, 13, 14, 17, 57] how often spine fusion successfully occurs following this operative procedure, and to answer the question, an end-result study of the spine-fusion operation has been carried out.

MATERIAL FOR STUDY

All cases of spine fusion performed at the New York Orthopaedic Dispensary and Hospital from 1936 through 1945 have been reviewed. During this period, spine fusion was performed on 1250 patients. Of this number, 154 patients were not followed for one year after the operation and have been excluded from the study. Of the 1096 patients who have been followed, the results of operation are known; by this we mean that each patient has had repeated clinical examination and roentgenographic study for a year or more after operation. Multiple-stage procedures were performed in many cases. In the cases followed, a total of 1504 spine-fusion procedures have been carried out.

The Hibbs technique of spine fusion has been used in all of the cases [33, 35, 36, 37, 40]. The results shown here represent the efforts of the most experienced staff members, as well as those of surgeons performing their first spine fusion, under supervision. Although the Hospital staff has employed minor variations in technique, the technique of operation now being performed at the Hospital includes certain definite standardized steps [40]. Postoperative care, including immobilization, has also been generally standardized. An attempt to secure internal fixation has been considered a sufficient departure from the usual technique to warrant separate analysis. There were no operative deaths during the period of this study. The number of cases represented in each group are shown in Table I.

DIAGNOSIS OF PSEUDARTHROSIS

The diagnosis of pseudarthrosis was made after consideration of the clinical picture and

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roentgenographic findings. Localized pain and tenderness, and the progression of deformity or disease, when present, aided in the establishment of the diagnosis. Study of lateral roentgenograms of the fusion area, with the patient first in the flexed and then in the extended position, has been especially useful. In certain cases the diagnosis of pseudarthrosis could not be made until the fusion area had been surgically explored. Exploration was always advised when any doubt existed as to the state of fusion. Relatively few of the patients in whom pseudarthrosis was suspected were unwilling to submit to exploration when it was suggested. The thoroughness of the search for pseudarthrosis in these patients is shown by the fact that, in twenty-three patients who underwent exploration, a solid fusion was found. For this reason the authors feel that there were very few patients in the entire group of 1096 cases in whom the status of the fusion was questionable.

INCIDENCE OF PSEUDARTHROSIS

Scoliosis (Table I)

During the period of this study, 376 patients with scoliosis underwent spine fusion and have been followed for at least one year after removal of the final jacket. A total of 744 primary operative procedures were carried out.

Of this group of patients, the diagnosis of pseudarthrosis at one, or more than one, level was made in fifty-nine. Thus, fusion failed in 15.6 per cent. of all the patients with scoliosis who underwent the operation, or in 7.9 per cent. of all the operations performed. In fifty-one patients, the diagnosis was confirmed at exploration. In the remaining eight patients, the diagnosis was made only by clinical and roentgenographic study. In this group, permission for exploration was denied, but the evidence which was obtained indicated the presence or the possibility of pseudarthrosis, and these patients have been included in the group to illustrate failure of fusion.

Fifty-one patients underwent repair of the fusion defect. Exploration for pseudarthrosis was performed in fourteen more patients, and solid fusion was found. The clinical features of pain and localized tenderness, and roentgenographic evidence of fusion defect and loss of correction, warranted such exploration. Thus, of the group of sixty-five patients who underwent exploration for pseudarthrosis, the preoperative diagnosis was confirmed in fifty-one, or 78.4 per cent. of the cases.

Lumbosacral Fusion

This group includes all cases of lumbosacral fusion from the fifth lumbar vertebra to the sacrum, and from the fourth lumbar vertebra to the sacrum. Fusion for spondylolisthesis and fusion with the use of internal fixation are treated separately. Exploration for herniated disc is now done with little or no sacrifice of lamina; thus, the technique of the Hibbs operation does not need to be altered greatly when combined with disc exploration. The combined type of operation has been included in this group because it is felt that the operation, as it is now performed, would have little or no effect on the incidence of pseudarthrosis. This was not true during the early days of the development of this operation, when a great part of the lamina was sacrificed. The operation, as it is now performed, has been done since 1940; statistics applying to the four years in which the more extensive type of exploration was done have been included in this study.

Four hundred and thirty patients with fusion from the fourth lumbar vertebra to the sacrum, or from the fifth lumbar vertebra to the sacrum, with or without exploration for a herniated disc, have been followed during this period, and the results of operation are known. Of this number, the diagnosis of pseudarthrosis has been made in sixty patients, or 13.9 per cent. of all the cases followed. In fifty-one patients, the diagnosis was confirmed by exploration, and the defect was repaired.

TABLE I

INCIDENCE OF PSEUDARTHROSIS AFTER SPINE FUSION

Condition	No. of Patients	No. of Operations	Failures		
			Patients (*No.*)	Patients (*Per cent.*)	Operations (*Per cent.*)
Scoliosis	376	744	59	15.6	7.9
Lumbosacral fusion					
Fifth lumbar to sacrum	261	261	20	7.6	
Fourth lumbar to sacrum	169	169	40	23.6	
Lumbosacral fusion (with internal fixation)					
Fifth lumbar to sacrum	41	41	5	12.1	
Fourth lumbar to sacrum	49	49	27	55.1	
Spondylolisthesis	65	65	9	13.8	
Tuberculosis	101	141	21	20.7	14.8
Miscellaneous	34	34	1		
Total	1096	1504	182	16.6	12.1

Nine patients in this group refused exploration for pseudarthrosis. Clinical and roentgenographic findings, suggestive of failure of fusion, warrant their inclusion in this group with pseudarthrosis.

Eight patients underwent exploration for pseudarthrosis, and solid fusion was found; thus, of the fifty-nine patients who underwent exploration, with the preoperative diagnosis of pseudarthrosis, confirmation of pseudarthrosis was found at operation in fifty-one, or 86.4 per cent.

Of the 261 patients who were included in the group with fusion from the fifth lumbar vertebra to the sacrum, with or without disc exploration, the diagnosis of pseudarthrosis has been made in twenty patients, or 7.6 per cent. of the cases followed. Of the 169 patients who underwent fusion from the fourth lumbar vertebra to the sacrum, pseudarthrosis developed in forty, or 23.6 per cent. of the cases followed. The figures shown here are evidence of the increased risk of pseudarthrosis, when the fusion is extended from the sacrum to the fourth lumbar vertebra, rather than to the fifth.

Of the forty cases of pseudarthrosis which occurred in the group with fusion from the fourth lumbar vertebra to the sacrum, thirty showed fusion defect at the level of the fourth to fifth lumbar vertebra; seven at the lumbosacral level; and, in three cases, pseudarthrosis developed at both levels.

Internal Fixation

In an attempt to allow early ambulation after spine fusion, the employment of some type of internal fixation has been added to the usual technique of spine fusion [43,59]. At this Hospital, it has been attempted by performing the usual type of operation and, in addition, by driving a stainless-steel machine screw of proper length across each of the apophyseal joints involved in the fusion. The patient is allowed out of bed at the end of two or three weeks, and no attempt is made to employ external support *.

Forty-nine patients in whom this technique was employed have been followed, each with fusion from the fourth lumbar vertebra to the sacrum. Pseudarthrosis developed in twenty-seven patients, or 55.1 per cent. of the group. The diagnosis was confirmed by exploration in nineteen cases, and repair was attempted. Of forty-one patients in whom

* Recently, some type of external support, usually a plaster jacket, has been applied to these patients, several days after operation, and has been maintained from six to twelve weeks. The patients have remained in bed during this period.

the fifth lumbar vertebra was fused to the sacrum and internal fixation was employed, failure of fusion developed in five, or 12.2 per cent. of the cases. In four of these, the pseudarthrosis has been confirmed by exploration.

Spondylolisthesis

This group has been considered separately because of the degree of instability of the involved vertebrae found in such cases. Sixty-five patients in whom fusion was attempted have been followed during this period. In seven patients, fusion was from the third lumbar vertebra to the sacrum. In the others, fusion was from the fourth lumbar vertebra to the sacrum. There was failure of fusion in nine patients, or 13.8 per cent. of the cases followed. Three patients showed failure of fusion both at the level of the fourth to fifth lumbar vertebrae and at the lumbosacral level. Four showed failure at only the level of the fourth to the fifth lumbar vertebrae, and two showed failure at only the lumbosacral level. In two patients in this group, exploration was carried out for suspected failure of fusion, and solid union was found.

Fusion for Tuberculosis

The postoperative care in these cases has varied according to the indications in the individual patient. Bed rest and some form of external support, either a spine brace or a plaster jacket incorporating both thighs, has been maintained until arrest of the disease was evident.

During the period of this study, 101 patients with spine fusion for tuberculosis were followed for at least one year after operation, and the results of the operation are known. A total of 141 primary operative procedures were performed in the cases followed. In twenty-one patients pseudarthrosis developed at one, or more than one, level. Thus, in 20.7 per cent. of all the patients followed, or 14.8 per cent. of all operative procedures, failure of fusion has resulted. The diagnosis has been confirmed by exploration in eighteen patients, and the defect has been repaired.

Four patients underwent exploration for what was thought to be a fusion failure, but solid union was found.

Miscellaneous Group

In this group are included cases of fusion for old fracture, localized osteo-arthritis at other than the lumbosacral level, and cases of wedging round-back. Thirty-four patients who underwent fusion were followed during this period. One patient showed failure of fusion at the level of the twelfth thoracic to the first lumbar vertebra; this has not been repaired.

EXTRA BONE

Frequently, because the usual technique did not supply enough bone to ensure fusion, the surgeon has used additional fresh autogenous bone. This has been obtained from the ilium or from the tibia.

Of the group of patients fused for scoliosis, extra bone was used in seventy-four; pseudarthrosis developed in thirteen of these patients, or 17.5 per cent. Thus, the incidence of occurrence of pseudarthrosis is slightly greater in this group than in the entire group fused for scoliosis. Extra bone was used in forty-two patients fused for spondylolisthesis. In six patients, or 14.2 per cent. of the group, pseudarthrosis developed. In twelve patients in whom fusion was from the fourth lumbar vertebra to the sacrum, and in five patients in whom fusion was from the fifth lumbar vertebra to the sacrum, additional bone from the ilium was added. Pseudarthrosis developed in two of the first group and in none of the latter group.

SUMMARY

A study of the results of all spine-fusion operations performed during the ten-year period from 1936 through 1945, at the New York Orthopaedic Dispensary and Hospital, shows that, of the 1096 patients followed at least one year from the time of spine fusion, the incidence of pseudarthrosis has been 16.6 per cent.

The diagnosis of pseudarthrosis can be made, in most cases, after careful clinical and roentgenographic evaluation. In a smaller group of cases, the diagnosis will not be definitely established until the area of fusion has been explored.

The benefits of the operation of spine fusion for any disease or deformity of the spine cannot be determined except in patients in whom a successful fusion has been definitely obtained.

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INTRA-UTERINE FRACTURES OF THE TIBIA AND FIBULA

Report of a Case with Correction by Osteotomy and Plating

BY GEORGE R. DAWSON, JR., M.D., FLORENCE, SOUTH CAROLINA

From Roper Hospital, Charleston, South Carolina

Intra-uterine fractures may occur in several ways. The first suggestion is trauma during pregnancy with indirect injury to the foetus. Amniotic snaring off is another possibility, and was definitely the cause in the cases of Granzow and Koch.

Diseases of the foetus to be considered in intra-uterine fracture are: (1) osteogenesis imperfecta, (2) chondrodystrophies, and (3) syphilis. Roentgenograms showing repair of a fracture in normal bone should rule these out. There have been many reports of pathological intra-uterine fractures; for example, Snure reported over two hundred in cases of osteopsathyrosis. A roentgenogram taken the first day or two after birth, showing either healing of normal bone or evidence of some bone lesion, would rule out an obstetrical fracture.

The criteria for a true intra-uterine fracture of normal bone are roentgenograms showing absence of disease and normal repair of a fractured bone. These films should be taken soon after birth, since callus forms so quickly in the newborn that roentgenograms taken even a week after delivery would not rule out a birth fracture.

CASE REPORT

A white male baby (No. 34142) was seen on May 20, 1942, one day after delivery. The delivery had

Fig. 1-A

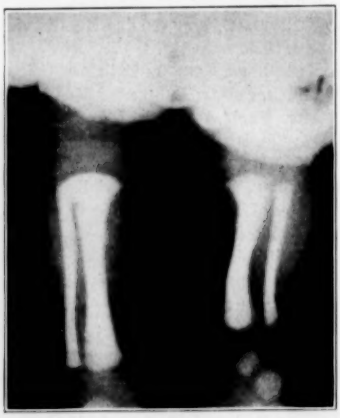

Fig. 1-B

Roentgenograms taken on May 23, 1942, three days after birth. The line of the intra-uterine fracture at the junction of the lower and middle thirds of the left tibia is almost obliterated. It can be seen in the lateral view, but not in the anteroposterior view. The fracture line in the fibula has been completely obliterated. Posterior bowing at the fracture site is 40 degrees in the lateral view, and medial bowing is 20 degrees in the anteroposterior view. Bone texture is normal. Length of the right tibia is 6 centimeters; that of the left tibia is 4.5 centimeters.

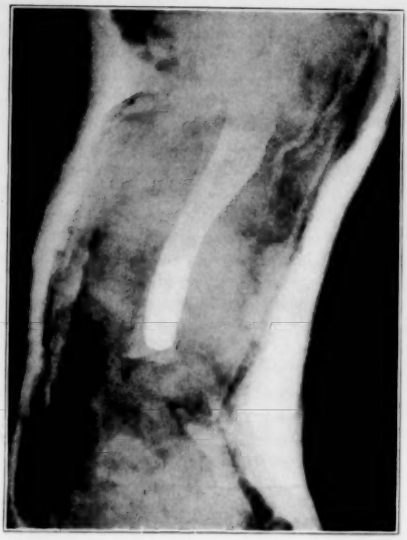

FIG. 2-A

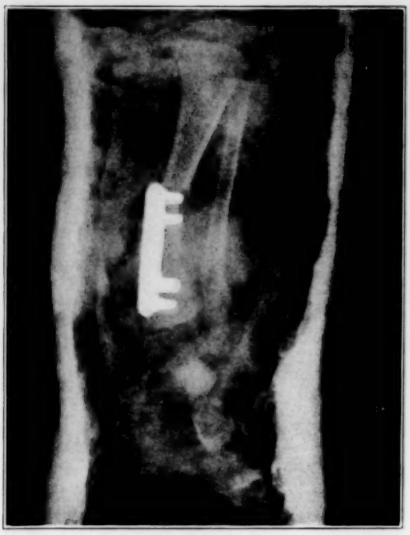

FIG. 2-B

Roentgenograms taken on August 19, 1942, two days after operation and three months after birth. The bowing at the site of intra-uterine fracture has been corrected completely, but a greenstick fracture is present at the upper screw, where posterior bowing is 15 degrees and medial bowing is 20 degrees. The lower end of the plate is 6 centimeters from the proximal tibial epiphyseal line and 0.3 centimeter from the distal tibial epiphyseal line.

FIG. 3-A

FIG. 3-B

Roentgenograms taken on August 21, 1947, five years after osteotomy. At the site of the intra-uterine fracture, the medial bowing has decreased to 12 degrees. Length of the right tibia is 18.6 centimeters; that of the left tibia is 17.8 centimeters.

FIG. 4-A FIG. 4-B

Photographs taken in September 1947. The medial bowing of the left tibia is not noticeable clinically. The left tibia is 0.8 centimeter shorter than the right, as measured in the anteroposterior roentgenograms.

been an easy one. Physical examination showed a normal baby except for the lower extremities. Calcaneovalgus was present bilaterally. The left leg was bowed 40 degrees clinically at the junction of the lower and middle thirds of the tibia and fibula. This accentuated the calcaneovalgus to such a degree that the foot lay against the anterior surface of the leg. The foot could be plantarflexed from extreme calcaneovalgus to 80 degrees. Roentgenograms taken three days after birth (Figs. 1-A and 1-B) showed a faint fracture line and considerable thickening at the junction of the lower and middle thirds of the tibia. Extreme posterior bowing was present in the lateral view, and slight medial bowing was present in the anteroposterior view. Clinically, the posterior bowing of the lower portions of the tibia and fibula looked much worse than it did by roentgenogram. The Wassermann reaction and other laboratory findings were negative.

The diagnosis of intra-uterine fracture of the lower portions of the tibia and fibula was made, as from the normal bone texture seen in the roentgenograms, other diagnoses seemed remote. Since the fracture line was almost obliterated, it was estimated that the fracture had taken place between two and three weeks before delivery. There was no history of a fall or of other injury to the mother. The films were reviewed by Albert Ferguson, M.D., who confirmed the diagnosis of intra-uterine fracture.

The bilateral calcaneovalgus was corrected easily by application of a series of four plaster casts.

Roentgenograms, taken when the infant was six weeks of age, showed posterior bowing of 35 degrees at the junction of the lower and middle thirds of the tibia and fibula, and medial bowing of 25 degrees. A corrective osteotomy was performed at twelve weeks of age at the apex of the posterior bowing, one inch above the distal tibial epiphyseal line. When the posterior bowing had been corrected, there was a V-shaped gap with the open part of the V forward. The posterior bowing was corrected entirely and the medial bowing was almost fully corrected. The position was held by a small forearm plate and four screws of 18–8 SMo stainless steel.

Postreduction roentgenograms (Figs. 2-A and 2-B) showed both the posterior and medial bowing to be corrected; however, there was 20 degrees of medial bowing at the site of a greenstick fracture which had occurred at the upper screw. Convalescence was uneventful.

Roentgenograms taken when the child was five years of age (Figs. 3-A and 3-B) showed that the posterior bowing had remained corrected; the medial bowing at the site of the intra-uterine fracture had decreased to 12 degrees. At the age of five and one-half years, the patient's left leg looked normal (Figs. 4-A and 4-B).

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MUSCLE TRANSPLANTATION FOR TRICEPS PALSY

The Technique of Utilizing the Latissimus Dorsi *

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Although the triceps is not a key muscle in the arm, the loss of its use is reflected in a varying degree of ataxia in the upper extremity. This is particularly noticeable in persons who have other muscle paralyses or weakness in the same extremity,—for example, those suffering from the after-effects of poliomyelitis, and others who have triceps weakness combined with various types of weakness affecting the finger flexors. The latter conditions are commonly seen in persons who have had a combination of injuries to the radial and ulnar nerves or to the radial and median nerves. A strongly functioning triceps is required for the effective use of crutches; and extension of the entire upper extremity is impaired by weakened or absent forearm extension due to triceps palsy. It is desirable to have numerous possibilities for surgical rehabilitation of the upper extremities.

Muscle transplants for strengthening forearm extension have not received sufficient attention, as many orthopaedic surgeons consider the disability due to isolated triceps palsy as minimal, because of the favorable effect of gravity in securing elbow extension in many positions of the upper extremity. Ober and Barr have proposed posterior transplantation of the muscle belly of the brachioradialis for triceps palsy. Unfortunately, many of the patients who desire the strengthening of extension at the elbow also have weakness or paralysis of the biceps and brachioradialis. On the other hand, in patients demonstrating the after-effects of poliomyelitis, the latissimus dorsi may be intact. This muscle is ideal for substitution of the triceps for the following reasons:

1. It often is of normal or nearly normal strength in persons who have weakness of the triceps and other arm and forearm muscles;

2. Its tendon and distal muscle fibers can be mobilized medially for a distance of six or more inches;

3. The nerve supply of the latissimus dorsi (the thoracodorsal nerve) is a free-lying trunk, from five to seven inches (12.5 to 17.5 centimeters) in length†, which is highly mobile and easily identified;

4. The blood supply of the latissimus dorsi enters from a wide zone in the proximal third of the muscle;

5. The operation of mobilizing the tendon of the latissimus dorsi and transferring it to the aponeurosis of the triceps is accomplished in a single, relatively restricted area in the posterior upper two thirds of the arm (Fig. 1).

OPERATIVE TECHNIQUE

The operation is carried out with the patient lying on his side in a slightly anterior oblique position, with the involved extremity uppermost. The skin incision (Fig. 1,*a*) begins one inch posterior and below the posterior inferior acromial tip, extending laterally for two inches and then downward over half the length of the upper portion of the arm at the posterior mid-line. The deltoid, latissimus dorsi, teres major, and the long head of the triceps are readily identified, since these are the muscles which give substance to the posterior axillary fold. The latissimus dorsi (and, if necessary, the teres major) is easily detached from its insertion into the medial bicipital ridge of the humerus; it is then

* This study was aided by a grant from the National Foundation for Infantile Paralysis, Inc.

† Measurements made by the author on thirty-three cadavera.

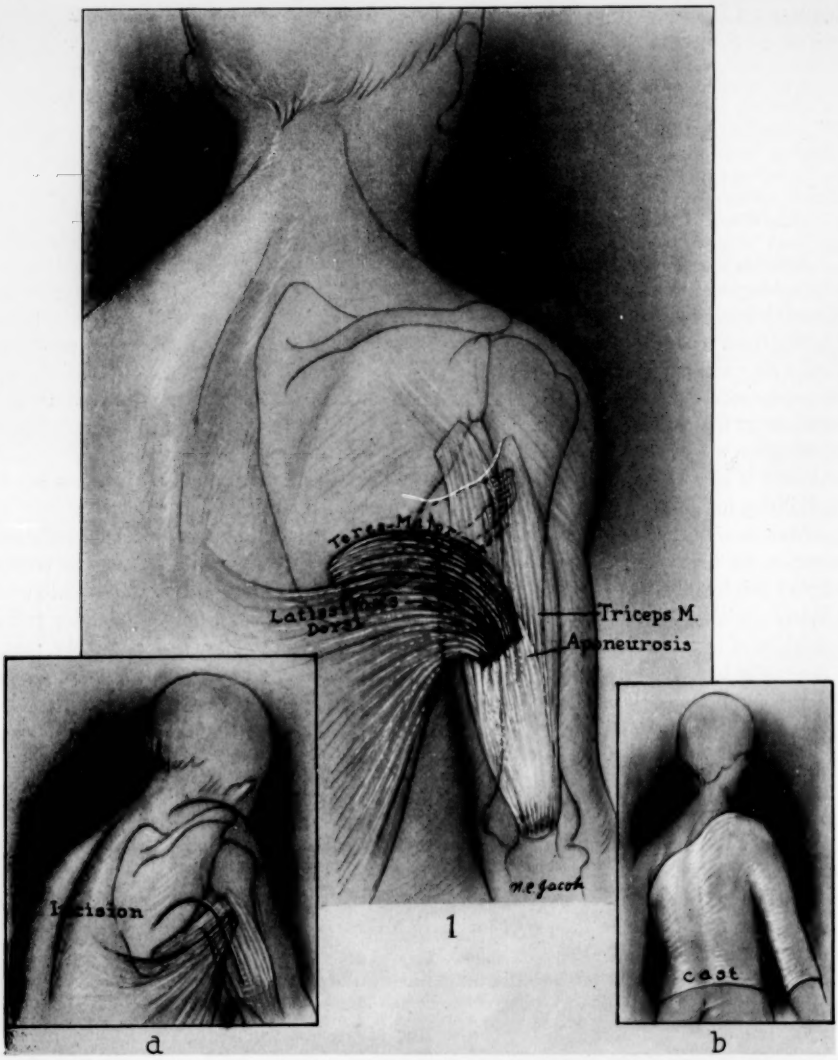

FIG. 1

Diagrammatic representation of surgical technique of transferring the latissimus dorsi and teres major into the triceps aponeurosis for the purpose of restoring extension of the elbow in triceps palsy. Inset *a*, the skin incision. Inset *b*, position of immobilization in the cast.

freed of loose connective tissue, and is directed downward in line with the long head of the triceps, and fixed to the triceps aponeurosis with interrupted non-absorbable stitches (Fig. 1).

Caution should be observed when freeing the latissimus dorsi from its insertion and in the dissection immediately preceding and following this procedure. The upper portion of the radial nerve lies just anterior to the tendons of the latissimus dorsi and the teres major. The trunk of the ulnar nerve and the axillary artery and veins are in close proximity, slightly more anterior at this same level. Attention should also be given to the structures which emerge from the quadrilateral space (posterior circumflex vessels, axillary

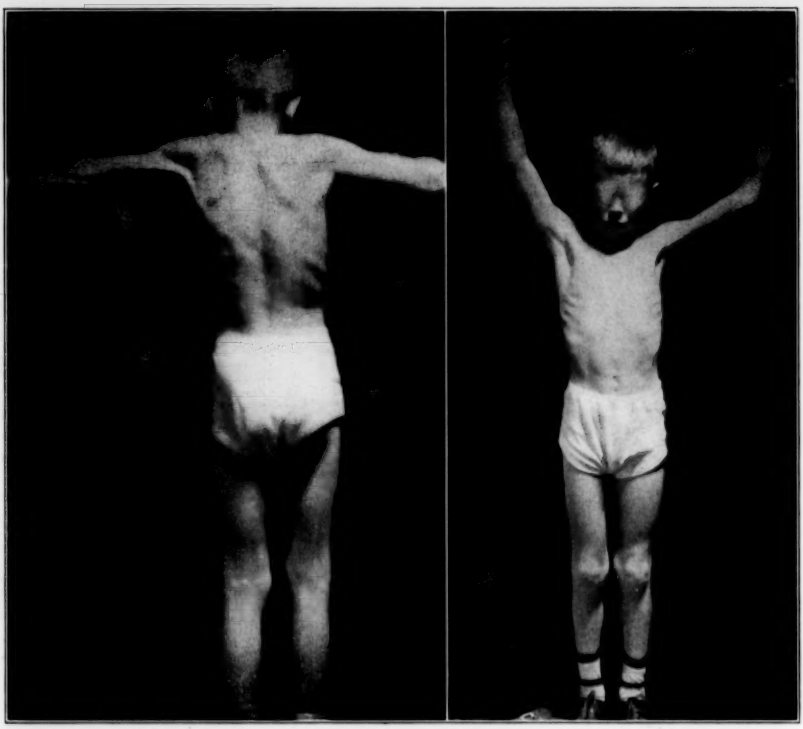

FIG. 2-A FIG. 2-B

Appearance of the patient prior to transplantation of the latissimus dorsi and teres major.
Fig. 2-A: Showing inability to maintain extension of the left elbow.
Fig. 2-B: Showing the only position in which boy could balance the forearm on the arm in semi-extension.

nerve and its branches, including the lateral brachial cutaneous nerve) by avoiding this area. This can easily be done by keeping the dissection deep and distal in relation to the posterior deltoid margin. When the posterior deltoid is atrophic, these structures are more likely to be encountered.

The report of an ideal end result from this operation is described below. In this case both the latissimus dorsi and the teres major were utilized for the transplantation.

D. L. M., aged ten, had an almost complete paralysis of the left triceps and lack of true opposition of the left thumb, twenty-two months after an acute attack of poliomyelitis. The patient was unable even to initiate elbow extension in any position of the upper extremity except in the arm-at-side position (Fig. 2-A). This distribution of paralysis had been stationary for the preceding sixteen months. Other muscles of the left upper extremity, although slightly atrophic, were functioning normally. On August 15, 1947, the latissimus dorsi and the teres major on the left were freed from their humeral insertions and mobilized proximally. It was found that the arm-at-the-side position was optimal for the most distal anchorage of the tendons of the two muscles into the triceps aponeurosis (Fig. 1). This same position was utilized for postoperative immobilization (Fig. 1,*b*).

The cast was removed three and one-half weeks after the operation. It was noted that some degree of extension of the forearm against gravity was possible on this same day. Strength of extension quickly improved. Five and one-half weeks after operation the range and strength of elbow extension, with the humerus abducted 90 degrees or more, were almost the same in the left arm, which had been operated upon, as in the normal right arm (Figs. 3-A, 3-B, and 3-C). Overhead elevation at the left shoulder was 10 degrees less than that of the right shoulder at this time, but this small discrepancy disappeared. Three months later, the only difference detected between the left arm and the normal right arm was the slightly lower position of the left posterior axillary fold, due to the direction taken by the bellies of the transplanted muscles. Strength and

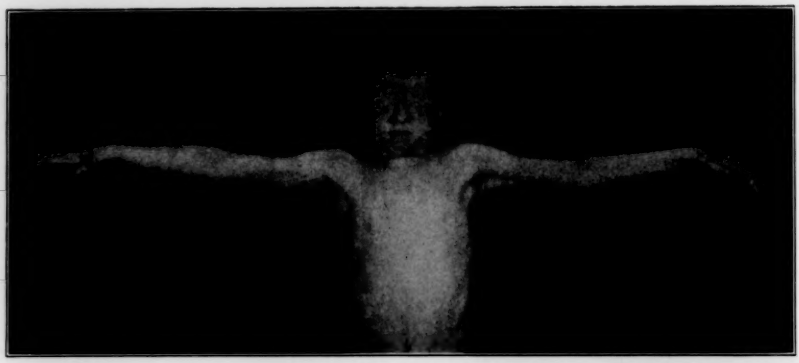

FIG. 3-A

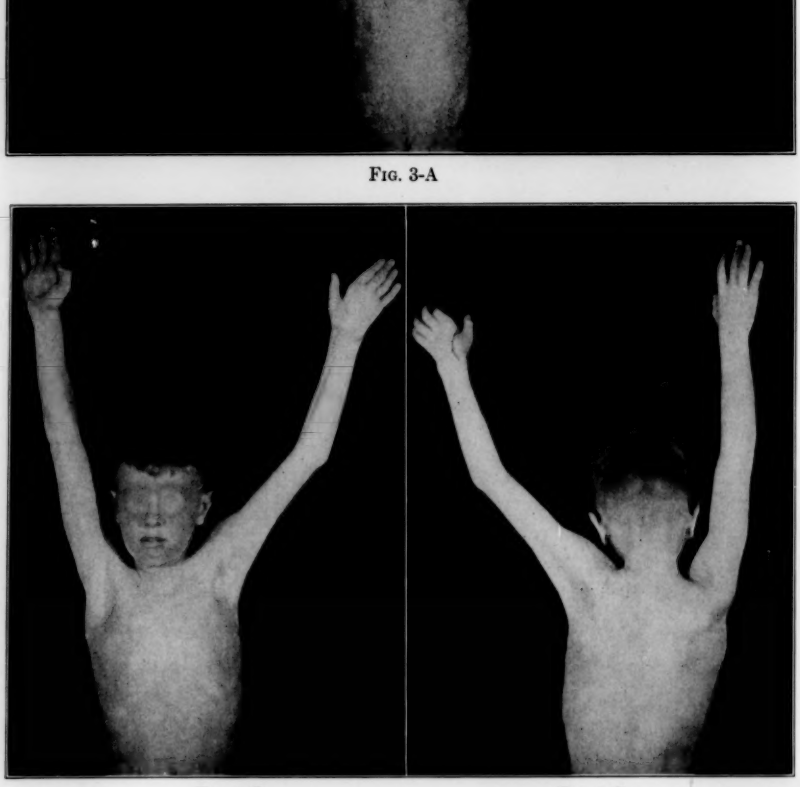

FIG. 3-B FIG. 3-C

Appearance of the patient five and one-half weeks after the operation and two weeks after removal of the cast.

Fig. 3-A: Complete extension of forearm on arm can now be maintained in abduction to 90 degrees.

Fig. 3-B: Extent of over-the-head abduction. The left arm, which had been operated upon, compares favorably with the right (normal) arm at this early postoperative date. Later, abduction to the same degree was possible in both.

Fig. 3-C: Posterior view. Note the lowering of the posterior axillary web, due to the new course of the transplanted muscles.

range of motion at the shoulder and elbow were the same in both arms. The total postoperative period has now been eighteen months. The patient and his family regard the left upper extremity as normal, since a tendon transplantation for thumb opposition had been done at the same time as the operation described in this report.

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FIBROSARCOMA OF THE TIBIA FOLLOWING CHRONIC OSTEOMYELITIS

Report of a Case

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From the Department of Pathology, Kern General Hospital, Bakersfield

Although carcinoma may develop in a sinus tract at the site of chronic osteomyelitis, sarcoma complicating this condition is extremely rare. Geschickter [1] has seen only one case of osteomyelitis of the femur in which sarcoma developed subsequently in the affected bone. The case to be reported here illustrates the development of sarcoma in the tibia following long-standing osteomyelitis.

A. L., a physician, aged sixty-six, entered the Cook County Hospital on September 11, 1936. He stated that at the age of twenty-five, hematogenous osteomyelitis had developed in the lower third of the left tibia. Ten years later the bone had been curretted, in Berlin. Since then he had had recurrences approximately every four years, although he was not incapacitated. An ulcer had developed at the site of a sinus, thirty-five years before, and had persisted in spite of local medications. Three months before admission, a growth had appeared at the site of the ulcer. After two months, biopsy was performed at the Michael Reese Hospital.

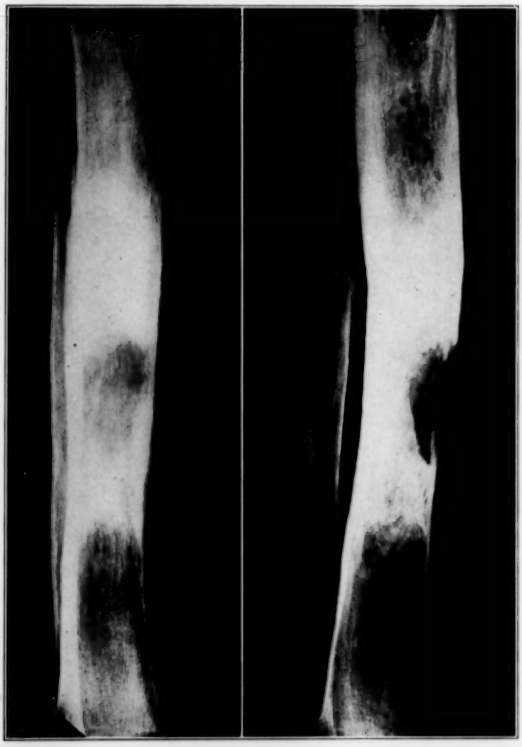

Fig. 1

Fig. 2

Fig. 1: September 1936. Chronic osteomyelitis of the left tibia with a secondary destructive lesion in the middle third.

Fig. 2: Photograph of the sectioned leg. Note the tumor, *T*, extending from the surface into the medulla of the tibia. Remaining portions of the tibia show the changes due to chronic osteomyelitis.

The pathologist's report (by Dr. Otto Saphir) stated that the biopsy revealed a fibrosarcoma. These sections were also seen by the late R. H. Jaffe, at Cook County Hospital, who concurred with Dr. Saphir's diagnosis.

Physical examination showed an ulcerated area, about two inches in diameter, from which protruded a fleshy mass; stasis pigmentation was seen about the ulcer. The examination was otherwise not remarkable.

Roentgenographic study, reported by the late Dr. Hubeney, disclosed that the left lower extremity was the site of an old osteomyelitis of the tibia, with a secondary destructive lesion and an accompanying advanced degree of arteriosclerosis (Fig. 1). Films of the chest showed no evidence of metastasis, but old adhesions of the diaphragm were present at the base of the right lung.

On September 12, amputation was done through the lower third of the left femur, following the administration of 500 cubic centimeters of whole blood. The patient made a satisfactory recovery.

Examination of the pathological specimen revealed an oval defect, 4 by 6 centimeters in diameter, in the lower third of the tibia, anteriorly. The lower margin was covered by soft, pinkish-tan, fleshy tissue. The popliteal artery was thin-walled and the lumen was patent. On sectioning in the region of the skin defect, a dense white tissue was found, which extended for thirty millimeters into the medullary substance. The medulla of the bone, above and below the tumor mass, was very dense (Fig. 2).

The defect in the bone was filled by tissue which varied in microscopic appearance. On the surface was a thick layer of necrotic tissue, which was mixed with blood and disintegrating pus cells. Beneath this was an abundance of loose fibrillar connective tissue with large fibrocytes, here and there infiltrated by small round cells. This connective tissue merged with a very dense connective tissue which surrounded irregular spicules of bone (Fig. 3). Attached to these spicules were rows of osteoblasts. Scattered throughout, but especially in the deeper portions, focal areas of great cellularity were present. In these areas the fibrocytes were very large, their nuclei were pleomorphic, and numerous mitotic figures could be seen (Fig. 4). The atypical fibrocytes often attached themselves to thin-walled capillaries and were mixed with small round cells and plasma cells (Fig. 5). At the edge of the sinus in the skin there was a marked proliferation of the surface epithelium, which often extended deep into the underlying connective tissue, forming anastomosing cords with small horn pearls. The histological picture was that of a fibrosarcoma of a moderate degree of malignancy, associated with

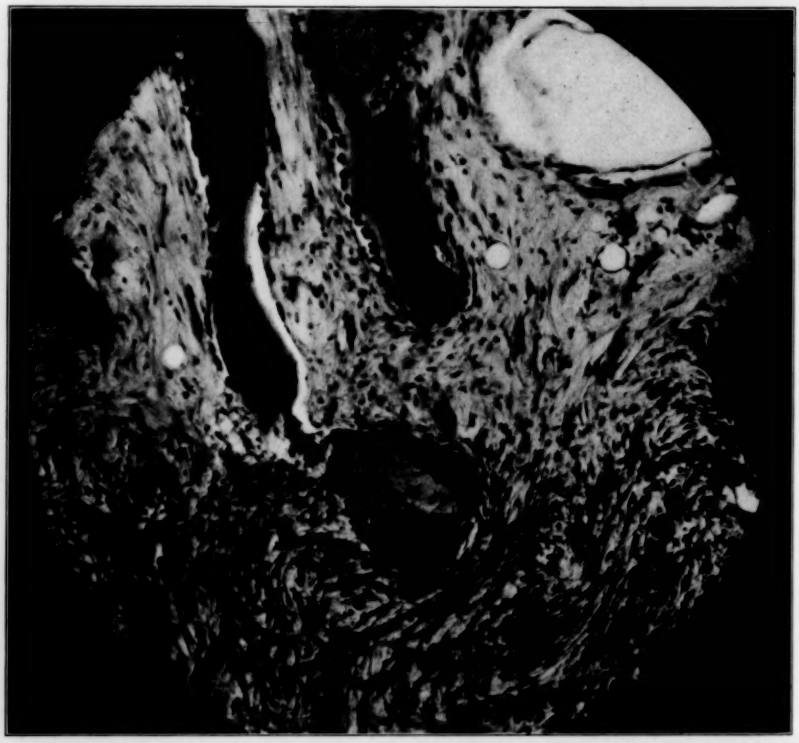

FIG. 3

Photomicrograph (×500) of section taken from tibia, distal to the tumor, to show the non-specific chronic inflammatory changes.

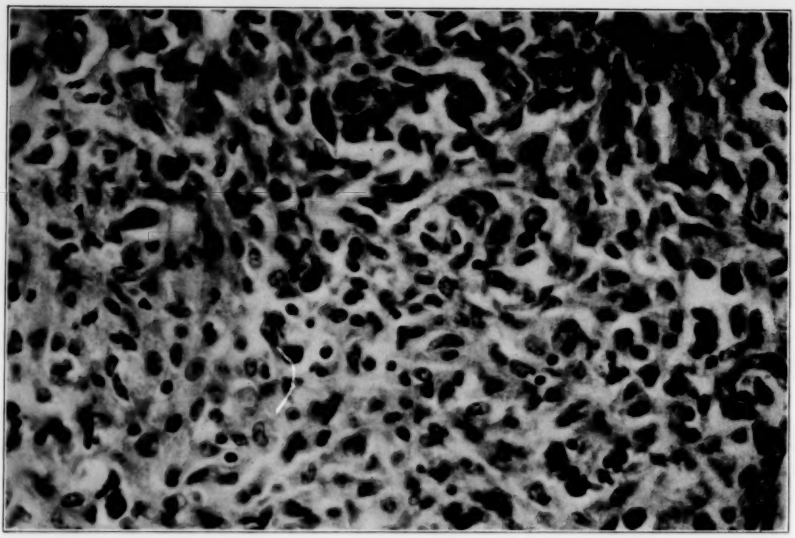

FIG. 4

Photomicrograph (×415) shows the fibroblastic appearance of the tumor. Section was taken from the deeper layer.

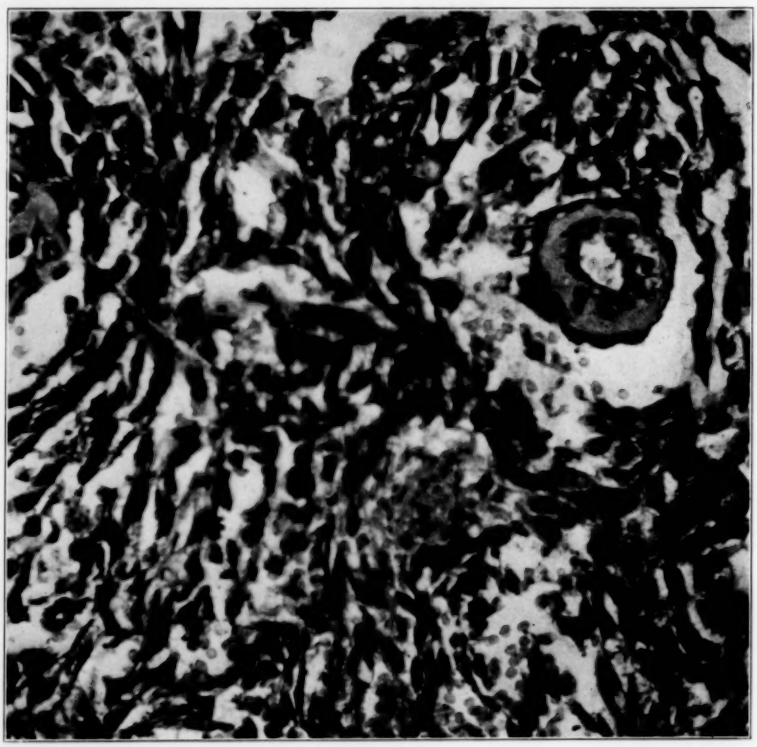

FIG. 5

Photomicrograph (×500) shows the spindle-cell character of the tumor, in section taken from a more superficial layer.

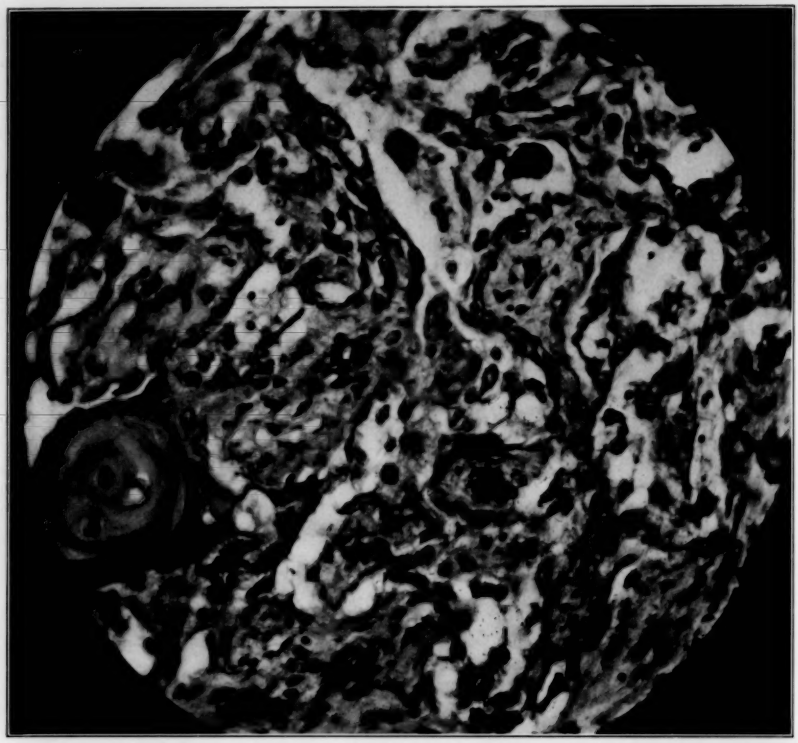

FIG. 6

Photomicrograph (×500) of section taken near the surface. Note single horn pearl, surrounded by granulation tissue with foreign-body giant cells.

chronic osteomyelitis of the tibia. The formation of horn pearls was probably a response of the inflammatory reaction and was not associated with an epidermoid carcinoma (Fig. 6).

The diagnosis of fibrosarcoma, made by biopsy, was subsequently confirmed by studies of the neoplasm removed from the amputated extremity. The patient was followed for three years, and no evidence of metastasis was found in that time.

SUMMARY

Sarcoma following a chronic inflammatory process in such regions as the kidney, liver, or breast is well known; and there is no reason why a neoplasm, such as fibrosarcoma, may not develop in bone which is the site of osteomyelitis. However, sarcoma in bone has rarely been preceded by osteomyelitis. The case described supports the theory of chronic inflammation as a predisposing factor in the formation of malignant neoplasms.

The tumor in this case probably had its origin in the fibrous bone marrow of the tibia.

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CALCIFICATION OF THE BURSAE OF THE KNEE*

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A search of the literature has failed to disclose any report of calcification of the bursae of the knees. However, Brantigan and Voshell stated that calcification of the superior bursa beneath the tibial collateral ligament might "account for certain cases of Pellegrini-Stieda disease". Search of the records of the Mayo Clinic then yielded eight cases of calcification of the bursae of the knee.

The more important bursae about the knee, of which eighteen or more have been described[1,2,3], are (1) the prepatellar bursa, located anterior to the lower half of the patella; (2) the infrapatellar bursa, located between the tibia and the lower portion of the patellar ligament; (3) the superficial pretibial bursa, located over the insertion of the patellar ligament; (4) variable bursae[1] situated below and above the collateral ligaments; and (5) numerous and variable popliteal bursae. Chief of the popliteal bursae is the gastrocnemius semimembranosus bursa. The popliteal bursae often communicate with the synovial cavity of the knee.

The exact mechanism of the production of heterotopic calcification is not known. The statement of Watson Jones and Roberts in this connection is of interest. They said that in bone, normal circulation results in normal calcification; increased circulation in decal-

FIG. 1-A FIG. 1-B

Case 6. Calcification in the prepatellar bursa of a woman fifty years old, as seen in the antero-posterior and lateral views.

* Abridgment of a portion of thesis presented by Dr. Norley to the faculty of the Graduate School of the University of Minnesota, in partial fulfillment of the requirements for the degree of Master of Science in Orthopaedic Surgery.

FIG. 2-A FIG. 2-B FIG. 2-C

Case 8. Calcified bursa over medial condyle of the femur of a woman, fifty-eight years old.
Fig. 2-A: Before injection of procaine hydrochloride into the bursa. Fig. 2-B: Five weeks later, deposits of calcium are being absorbed.
Fig. 2-C: Three and a half months after injection of procaine hydrochloride, calcium has disappeared completely.

cification; decreased circulation in increased calcification; and cutting off the blood supply in unchanged calcification. In any mesenchymatous tissue of low metabolism, decreased circulation results in pathological calcification, especially in the presence of fibrosis of trauma or infection. Fibroblasts plus an excess of calcium plus an adequate blood supply result in bone.

CLINICAL DATA

The eight patients complained of progressive pain on motion, of swelling, and of limited motion. Physical examination usually revealed a tender swelling over the involved bursa. Crepitus sometimes was present, in addition to limited motion. Calcification within the bursa was not usually suspected until its presence was revealed in the roentgenogram. One patient had recurrent painless swelling without any localizing signs, and the roentgenograms revealed calcification of the bursa over the medial condyle of the femur.

Of the eight patients studied, four gave a definite history of injury and most commonly of repeated traumata over a period of years. One patient, a man sixty years old, remembered no injury, but had a painless recurrent swelling of the knee. No injury was mentioned by the remaining three patients.

Locations of the calcified bursae were: prepatellar bursae in two cases (Figs. 1-A and 1-B), infrapatellar bursa in one, bursae over the medial femoral condyle in four, and bursa over the lateral epicondyle in one case.

TREATMENT AND RESULTS

As in the treatment of calcified bursae anywhere in the body, needling and the injection of procaine hydrochloride or surgical excision may be curative; the more conservative means should be used first if the symptoms are not too severe.

Needling and the injection of procaine hydrochloride were carried out in Case 8, in which the bursa was over the medial femoral condyle (Fig. 2-A); relief of symptoms and complete disappearance of the calcium were noted in three and a half months (Figs. 2-B and 2-C). This patient had associated diabetes and para-articular calcification of both hips. She had had seven diathermy and massage treatments in this same period.

Another patient (Case 1) had a calcified bursa excised from over the medial femoral condyle. One calcified prepatellar bursa was also removed surgically (Case 3). No follow-up data are available on these two patients. The roentgenograms in Case 3 were negative for calcification, but the gross specimen contained deposits of calcium. One other patient (Case 6) was advised to have a calcified prepatellar bursa removed surgically, but this was not done (Figs. 1-A and 1-B). One patient (Case 4) with a calcified bursa over the lateral femoral condyle had patellectomy for painful traumatic arthritis of the patella. One year later the patient reported a successful result from the patellectomy and no complaints referable to the knee. One other patient with similar calcification of a bursa over the medial femoral condyle was advised to have heat and massage to his knee. He had been kicked twice by a horse on the medial aspect of the knee and had had pain for five years. Calcification was not considered of significance in this case.

PATHOLOGICAL FEATURES

Microscopic examination of the two bursae removed surgically showed extensive deposits of amorphous calcium and inflammatory reaction within the bursal tissues.

COMMENT

Calcification may occur in any of the bursae about the knee and may cause disability and symptoms. Cures may be effected by local injection of procaine hydrochloride and needling or by surgical excision. This lesion is not common; it has been encountered only infrequently at the Mayo Clinic, and no report has appeared in the literature, as far as the authors could ascertain.

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AMPUTATION FOR DISCREPANCY OF LIMB LENGTH IN TUBERCULOSIS OF THE HIP

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Orthopaedic surgeons, in the not-too-distant past, have been accustomed to see, on their Services, patients with tuberculosis of the hip, lying in hip spicas for months or years, awaiting the "optimum" time for treatment.

Gill, in 1944, presented his succinct observations and hypotheses concerning the ravages of this so-called conservative procedure,—namely, that the severe osteoporosis resulting from prolonged immobilization produces profound changes in the bone about the distal femoral and proximal tibial epiphyses, making it susceptible to minimal trauma and resulting in growth impairment, deformity, and ultimately in marked limb-length discrepancy.

Ross, in a recent paper, reiterated Gill's observations that growth disturbances will result from such "treatment", but added to the list, headed by tuberculosis of the hip, any disease which causes or necessitates prolonged disability. He also claimed that growth retardation occurs before growth arrest, thus making the process reversible if the first stage, that of retarded growth, has not progressed to growth cessation. This can be demonstrated when the disability ends relatively soon, bringing to a close the period of uselessness of the extremity; then bone atrophy will diminish, the epiphysis will assume a more normal appearance, and limb-length discrepancy will not increase. His theory of the etiology of this condition differed from Gill's hypothesis.

Both authors agreed, however, that, in addition to the prolonged disability which produces the osteoporosis, trauma to the epiphysis is necessary to retard or to stop growth. Each hypothesized differently as to why the epiphyses are so susceptible and as to what constitutes the trauma. Gill felt that the soft, atrophic, almost liquid, degenerated bone on each side of the epiphyses causes buckling of the curtain-like cartilage plate, due to bending of this pliable area as a result of changes in the intramedullary pressure. This ruptures the epiphyseal plate or the small vessels going to it, thus damaging the growth center. Ross propounded the theory that the cartilage partially degenerates as the result of atrophy of disuse and, therefore, retards growth; that it is unable later to withstand added stress, because of the faulty gait resulting from deformities; and that

this finally causes growth arrest, as a result of complete degeneration of a portion of the epiphyseal plate and the repair of the defect so formed by a bony bridge.

Gill's hypothesis could explain deformities and growth arrest in patients who have *not* caused weight trauma to the epiphyses; but the change might result from trauma, occurring inadvertently at the time of cast changes, surgery, or manipulations. Ross, however, stressed that growth retardation and arrest occur most frequently in the areas where stress and strain are concentrated, and pointed out that the elastic cartilage resists fracture, which would indicate that weight-bearing is an etiological factor. We believe that both theories are important in explaining growth changes in these extremities after prolonged disability.

However, from both authors' views and from common experience, we think one should promulgate certain axioms concerning the prophylaxis of this serious complication, especially in tuberculosis of the hip, for certainly everyone should be in agreement about this phase of the problem:

1. Long periods of immobilization prior to surgery should be avoided.

2. An adequate arthrodesis should be performed as early as possible,—that is, as soon as the patient's condition permits. The criteria for judging the optimum time for surgery in these tuberculous patients are as follows:

   A. Weight stabilization or, preferably, weight gain;
   B. Slowing of the pulse rate with stabilization;
   C. Falling or stabilization of the temperature curve;
   D. Leveling of the sedimentation rate.

This concept has been advocated by Chandler for many years; and in Pease's recent paper [4], in which he presented a five-year follow-up of twenty-eight cases of tuberculosis of the hip with early arthrodesis, by the use of the Chandler technique [1], there was not one case of serious or even consequential growth retardation or arrest [5]. In contrast, McCarroll and Heath presented cases with major deformities and resulting marked limb-length discrepancies in a similar group of patients who were treated with prolonged immobilization prior to arthrodesis.

3. Weight-bearing in the spica cast to reverse the osteoporotic process by physiological stress should be started as soon as possible after surgery, usually within six weeks, with careful supervision of the patient's activity to prevent trauma to the epiphysis.

4. Handling an osteoporotic limb during cast changes, surgery, et cetera, should be done with extreme care, especially if the extremity is tender to any degree.

We believe there is also unanimity of opinion as to treatment when partial or complete growth delay, or arrest, occurs. Such procedures as completion of the arrest of incompletely fused epiphyses, equalization of limb length by epiphyseal arrest in the uninvolved extremity, limb-shortening and limb-lengthening operations, osteotomies to correct the deformities of tibia recurvata or tibia vara, or combinations of one or more of these, are indicated.

It is not within the scope of this paper to discuss these methods. However, the problem arises of what should be done if the patient has marked shortening with such severe deformities that a weight-bearing extremity cannot be restored, as is frequently seen and was strikingly demonstrated in McCarroll and Heath's recent series. A case is presented which posed such a problem, the solution of which will demonstrate a method for adequate treatment.

A white boy was first admitted to the University of Illinois, Orthopaedic Department, on May 7, 1937, at the age of three years. He was subacutely ill and his right hip was fixed at about 90 degrees of flexion, slight abduction, and external rotation. There was swelling, muscle spasm, and pain in this hip on palpation and motion. The patient had a fever of 100.6 degrees. There was an inadequate history of increasingly progressive difficulty with the extremity for about four months. Prior to the child's admission, his father had died of pulmonary tuberculosis; his mother was seriously ill with the same disease and died a few months later.

FIG. 1

FIG. 2

FIG. 3

Fig. 1: Roentgenogram showing arrest of the tuberculous lesion of the right hip by fusion of the joint.
Fig. 2: Photograph of patient's lower extremities shows the marked shortening, atrophy, and deformity of the right lower extremity as compared to the left.
Fig. 3: Roentgenograms of the right leg, revealing the marked bowing, asymmetry of the epiphyseal ends of the bones, thin tortuous fibula, and generalized bone atrophy.

atrophy.

FIG. 4

FIG. 5

Fig. 4: Roentgenograms of the right foot reveal the marked calcaneocavus deformity and severe osteoporosis.

Fig. 5: Roentgenograms of the knee, taken six months after fusion operation, show successful arthrodesis of the joint. The obliquity of the joint line, due to irregular closure of the epiphyseal lines (which, although closed, are still apparent), demonstrates the typical deformities seen about the knee after long immobilization of the lower extremity. (The site of amputation is in a portion of the leg distal to that shown in the roentgenograms.)

The patient's right lower extremity was placed in balanced traction. Aspiration of the hip-joint fluid was done about two weeks after admission. Approximately 30 cubic centimeters of thick, green, purulent material was removed for bacteriological examination and guinea-pig inoculation. The cultures were negative, but subsequent autopsies of guinea pigs corroborated the clinical impression of tuberculosis of the right hip.

The patient's deformity and muscle spasm improved as a result of traction, and about seven weeks after admission, a double hip-spica cast was applied. After seventeen months, during which several cast changes were made, the patient was discharged from the Hospital. His sedimentation rate had decreased to 3 millimeters per hour (Wintrobe method) and he was gaining weight.

The boy was followed in the Out-Patient Department for the next three years, having frequent cast changes, and on April 25, 1941, was readmitted to the Hospital for possible surgery. Because of a rather severe febrile reaction, another double hip-spica cast was applied with "manipulation of the knee in an attempt to overcorrect the varus deformity by forcing it into slight valgus". The foot also was manipulated, in an attempt to correct the calcaneovalgus. (This would tend to corroborate Gill's view that weight-bearing is not necessary to cause epiphyseal damage. This patient had not been bearing weight while in his cast.)

About six weeks after his readmission (June 16) an arthrodesis was performed on the right hip; a graft from the right fibula was driven up through the trochanter and neck into the ilium, and a cast was reapplied. The patient made an uneventful recovery and was discharged four months after operation (October 16). He was seen from time to time in the Out-Patient Department and his spica cast was changed periodically.

On July 3, 1942 (thirteen months after operation), there was failure of the arthrodesis, both clinically and roentgenographically. Another fusion of the hip was done on July 27; the regenerated right fibula was used as an extra-articular graft, wedged across the joint from trochanter to ilium. The postoperative course was again uneventful and the patient was discharged, six weeks after operation, in a double hip-spica cast. He was followed in the dispensary for the next year and, at the time his casts were changed, an increasing deformity of the tibia was noted with instability of the knee joint. Up to this time fusion of the hip had not occurred, and a single hip spica was applied on March 8, 1944, so that the patient could bear weight. On May 26, 1944, there was clinical and roentgenographic evidence of fusion (almost two years after his second operation), but a single hip spica was reapplied.

FIG. 6

FIG. 7

Fig. 6: Photograph after knee fusion and below-the-knee amputation. The end of the stump is at the same level as the opposite knee joint.

Fig. 7: Patient, at the time of discharge, wearing his prosthesis.

The patient was readmitted on May 14, 1945, at the age of eleven, almost eight years after his initial admission. At this time, his hip was fused (Fig. 1), but the right lower extremity was deformed and atrophic with 13.75 centimeters of shortening and a calcaneocavus deformity of the right foot (Figs. 2, 3, and 4). His general condition was good. Gastric washings and urine examination were negative for acid-fast organisms. Blood chemistry and serology were within normal limits.

On June 13, 1945, arthrodesis of the right knee was performed, the patella being used as a key graft, and a single hip spica was applied. Recovery was uneventful and, after the sutures had been removed, a snug-fitting spica with an extension caliper was applied (to equalize limb length) and the patient was allowed to be up.

On November 13, 1945 (five months after knee fusion), an amputation of the leg was performed (Figs. 5 and 6). As soon as the wound was healed, a pylon and a peg-leg were fitted so that the patient might be ambulatory. A prosthesis was then made and a rapid adjustment to it followed, in spite of the stiff hip, so that when the patient was discharged, on May 2, 1946, he was walking with an almost imperceptible limp, without support (Fig. 7).

Knee fusion and later amputation of the leg to "equalize" the femora are indicated in growing children, rather than a Gritti-Stokes or supracondylar tendoplasty type of amputation. In this case, at the time the knee fusion was done, the patient was eleven years of age and had an expected five years of growth. Assuming cessation of growth on the affected side (the right lower extremity), the uninvolved femur would grow two and one-half inches at the knee while the tibia would grow one and two-thirds inches at the knee, making a total increased length of at least four and one-sixth inches by the time growth stopped, at the age of sixteen. We can assume that the amputated stump would be that much shorter if an above-the-knee amputation had been done originally. The procedure described would, therefore, give the patient a much more satisfactory stump and a much more satisfactory prosthesis at the time he reached maximum growth.

SUMMARY AND CONCLUSIONS

In the case described, a typical patient with tuberculosis of the hip, who was treated for a long time in traction and many plaster casts, with manipulation of the extremity under anaesthesia to correct apparent deformity about the knee, had two operations upon the hip with further immobilization. When fusion of the joint finally occurred, the extremity was 13.75 centimeters shorter than its normal mate, and a calcaneocavus deformity of the foot was present.

The method of treating such a useless and unsightly extremity includes the following steps:

1. Fusion of the knee joint;
2. Amputation of the extremity, so that the end of the stump will be at the same level as the knee joint of the "good" leg;
3. Fitting the patient with the proper prosthesis, after rehabilitation and training by prior application of a walking pylon.

The excellent result in the case described warrants serious consideration of this method of treatment for an extensively deformed and shortened lower extremity, resulting from damage to the susceptible epiphyses during so-called "conservative" treatment of hip-joint tuberculosis or other disease requiring prolonged immobilization of the lower extremity.

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A SUCCESSFUL PROSTHESIS FOR SACRO-ILIAC DISARTICULATION (HEMIPELVECTOMY)

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From the Surgical Service, Veterans Hospital, Portland

A satisfactory weight-bearing prosthesis for patients with sacro-iliac disarticulation has not, to our knowledge, been reported previously. Amputation through the sacro-iliac joint with removal of the ilium, ischium, and pubis sacrifices all weight-bearing areas considered essential to a lower-extremity prosthesis.

While only 138 cases of sacro-iliac disarticulation had been reported prior to 1945, the operation is now being performed more frequently. Many years of arrest may be anticipated, and have actually been achieved, by the removal of some of the malignant tumors of the innominate bone. It is unfortunate to condemn these patients to a life on crutches.

Such was the consideration when a left sacro-iliac disarticulation (Fig. 1) was performed on patient R. T., aged thirty-eight, for a primary osteochondrosarcoma of the left ilium [1]. This operation was carried out on July 21, 1947, at the Veterans Hospital, Portland, Oregon. The convalescence was smooth and the patient was up on crutches, three weeks after the operation (Fig. 2).

Construction of a walking prosthesis was initiated three months after the operation. The essential problems to be solved were two: first, what areas could be used for weight-bearing, with the ischial tuberosity and thigh-amputation stump missing; and second, how stabilization of the prosthesis could be achieved with absence of the iliac crest.

It was first considered necessary to have three points of weight-bearing: (a) the left axilla, (b) the opposite ischial tuberosity, and (c) the trunk and lower rib cage. Actually, after construction of the hip basket, it was found that full weight-bearing could be taken on the trunk, including the lower thoracic rib cage and the left wing of the sacrum, through the remaining segment of the gluteal muscles in the posterior portion of the amputation. The portion of the left gluteal muscles in the posterior flap remaining after the amputation proved to be of great aid as an area of weight-bearing and stabilization. It is suggested that as large a portion of these muscles as possible, consistent with a wide removal of the tumor, be spared. There was found to be only three-eighths of an inch upward movement of the basket during full weight-bearing. Therefore, no additional weight-bearing

FIG. 1

Roentgenogram, following operation for removal of the left innominate bone.

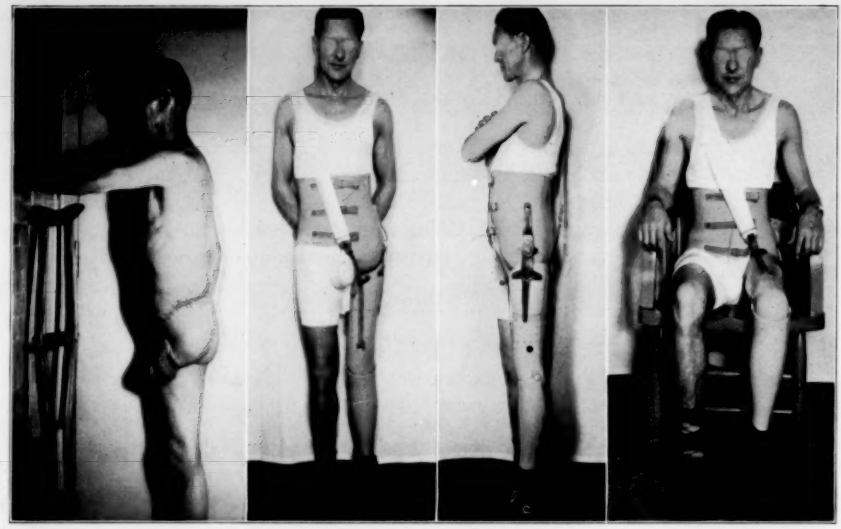

FIG. 2 FIG. 3 FIG. 4 FIG. 5

Fig. 2: Photograph of the healed amputation wound. (Reproduced, by permission of J. B. Lippincott Co., from Ann. Surg., **128:** 996, 1948.)
Figs. 3 and 4: Anterior and lateral views of patient with prosthesis in place.
Fig. 5: View of prosthesis with patient in sitting position.

points were necessary, obviating the need of an axillary crutch or an opposite ischial seat with the resultant restriction of trunk motion.

The stabilization and alignment of the prosthesis were a major consideration. Removal of half of the bony pelvis caused the lower trunk, opposite the remaining iliac crest, to assume a conical shape, making anchorage and alignment difficult. It was necessary to construct a false buttock in order to obtain the normal width and length of the removed hemipelvis. This portion of the prosthesis is made of balsa wood and cork, and is firmly anchored to the trunk portion by means of waterproof glue and rawhide (Figs. 3 and 4). Its inner surface is in contact with the posterior flap of the amputation. By construction of the trunk basket with buttock extension, stability and alignment were obtained in walking and sitting.

The attachment of the extremity portion of the prosthesis to the hip basket was a normal prosthetic procedure. The hip joint is furnished with a locking device, allowing flexion while the patient is sitting and locking in extension. The axis of the knee is set posteriorly about one inch, preventing buckling of the knee in normal walking.

The basket portion of the prosthesis is held around the trunk by three leather straps. The knee-control strap extends over the opposite shoulder, produces extension of the lower extremity, and aids in anchoring the entire prosthesis to the body.

The patient, when wearing the prosthesis, can walk with the aid of one cane. He is able to walk up and down stairs, one step at a time, and can bend forward to touch his finger tips to the floor. He can sit in normal position (Fig. 5) and can kneel.

NOTE: Published with permission of the Chief Medical Director, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or the conclusions drawn by the author.

The author wishes to express his appreciation to Mr. A. W. Pruhsmeier, brace-maker of Portland, Oregon, for his assistance in preparing the prosthesis described.

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MECHANICAL AIDS FOR PATIENTS WITH MUSCULAR DISABILITY

BY PAUL THOMAS YOUNG, PH.D., URBANA, ILLINOIS

The writer has had experience with several cases of a rare form of muscular dystrophy in which there is a generally retarded muscular development. With advancing age and increasing weight, the difficulty of locomotion is augmented. Arising from a chair of ordinary height becomes an arduous task. Going over stairs is laborious. With one patient, if the rise is more than seven inches, the step cannot be mounted without assistance.

To aid in meeting these difficulties, various mechanical aids have been evolved, through trial and error over a period of about thirty years. The present report describes two forms of secondary aid,—stepping-stick canes and self-rising chairs.

Stepping-Stick Canes

Figure 1 shows the evolution of a cane that is useful in negotiating steps which otherwise would be too high for the patient to mount without assistance. The original form of stepping stick, shown at the left, consists of a broom handle to which a block of wood has been attached. The block is three and one-half inches high and one and one-quarter inches thick; it is as wide as the patient's shoe. In using this stick, the patient grasps the handle with the right hand and places the sole of the right shoe on the block, as with an ordinary stilt. Then he lifts his weight to the block and swings forward, steadying himself with the handle. The block has the effect of breaking a seven-inch rise into two rises, each of three and one-half inches.

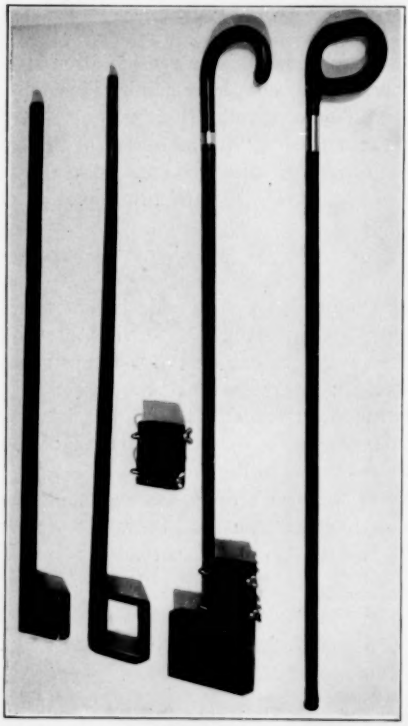

FIG. 1

In the second cane from the left, instead of a block of wood, a square iron frame, made by a blacksmith, has been bolted to a light stick. The stick is tapered, rounded, and made of suitable length. When not in use as a stepping stick it can be turned upside down, and the square base becomes a handle.

The third is an ordinary commercial cane to which blocks have been attached with butterfly nuts. A single block (shown detached) can be clamped to the cane and quickly removed. The block provides a step similar to that of the earlier models. In the illustration a two-stage block is shown. The first rise is three and one-half inches; the second is seven inches. From a height of seven inches the patient can step up to a height of ten or eleven inches. This two-stage block is useful, however, only when there is a railing or other means of steadying the body during ascent. It has proved practical for a person getting on a train or making similar climbs.

To give greater stability, a small aluminum ladder attached to a stick (not shown) has been made. This is virtually a light-weight stepladder, made to suit the patient, which can be lifted from step to step by the handle. One such ladder, now in use, has three steps.

At the right of Figure 1 is an ordinary rubber-tipped cane with a painted head of aluminum alloy. This stepping stick resembles an ordinary cane; but, when turned upside down, the head can be used to enable the patient to negotiate a seven-inch step. The metal head can be unscrewed and a curved wooden handle inserted for use when the patient is walking on the level.

These devices make it possible for the patient to go over curbstones and steps which could otherwise not be climbed without aid.

Self-Rising Chairs

When the extensor muscles of the legs are too weak to lift the weight of the body from a sitting to a standing position, it is difficult for the patient to arise from a chair of ordinary height. However, he is able to walk on the level.

To meet this difficulty a small solid cushion, resembling a case, is placed on a chair. It is strong enough to hold the patient's weight and it raises the height of a chair about three inches,—just enough to make the difference between getting up with moderate ease and getting up awkwardly or, perhaps, not without help. The cushion is nine by twelve and one-half inches in cross section.

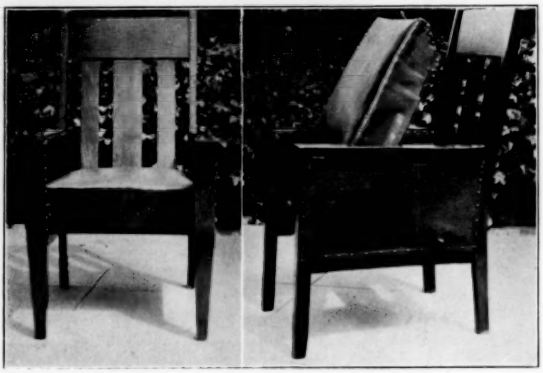

FIG. 2-A

FIG. 2-B

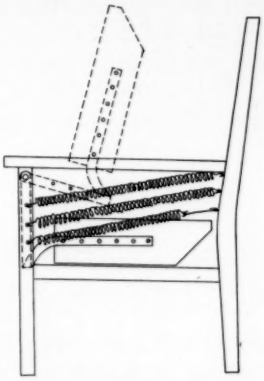

FIG. 3

In the home this problem has been solved differently. For ten years one patient with muscular dystrophy successfully used a special chair with a self-rising seat. Figures 2-A and 2-B show a dining-room chair made of quarter-sawed oak and leather. When the seat is lowered and locked (Fig. 2-A), the chair resembles an ordinary master's chair of a dining-room set. A spring mechanism, concealed in the sides by leather covering, lifts the seat to the raised position shown in Figure 2-B. A strong cupboard lock serves to hold the seat down, and this can be released by pulling a lever forward. The lever is shown at *L*.

As the patient places his weight against the raised seat, the seat lowers and steel extension springs in the side become tense. The tension counterbalances the weight of the patient, and in the lower position the seat can give an initial upward boost of about forty pounds, sufficient to enable the patient to arise with ease. The number of springs and the tension are, of course, varied to suit the requirements of the patient. The springs counterbalance the weight of the seat and much of the weight of the patient as he sits down. Upon arising, he literally springs to his feet.

Figure 3 shows the mechanical details of this chair, with the seat in the lowered position and the springs attached and stretched. The position of the seat, when raised, is indicated by broken lines. To swing the seat properly, two special iron braces are needed. As seen from the front with seat lowered, each brace resembles a J; one J turns to the right and the other to the left. The braces are pivoted at the top of the J and the exten-

sion springs are attached to the long vertical bar. In side view, one can observe that the lower tip of the J is curved upward and backward, so that it can be bolted firmly to the wooden frame of the seat.

Experimentation with several styles of self-rising chairs has brought to light an important principle: The rising seat should be pivoted as nearly as possible at the knee joint of the patient, or perhaps slightly in front and above the knee. In an unsuccessful model, the seat of an ordinary chair was hinged at the front edge. This seat, when partly raised, slid out from under the patient, leaving him suspended helplessly in mid-air. Thus, for mechanical reasons, the front edge of the seat must be several inches behind the front leg of the chair, as seen in Figures 2-A, 2-B, and 3.

In an overstuffed chair, extension springs, concealed within the sides, counterbalance the weight of the seat and enable the patient to spring to his feet from a comfortable seated position. A press button releases the lock mechanism which permits the seat to rise from the lower to the upper position. The seat can be locked down indefinitely, if desired; but this involves some risk, since a child can press the button to make the seat fly up and catapult whatever is upon it.

Possibly a self-rising chair would be serviceable to aged persons or to others who find it difficult to arise from a low chair or one of ordinary height. If the springs are carefully adjusted (and this can be done with a little trial and error), the self-rising chair easily and quickly brings the sitter to his feet.

At the present time no arrangements have been made for the manufacture of self-rising chairs and stepping-stick canes.

THE TREATMENT OF CONGENITAL CLUB-FOOT

Nine Years' Experience with a Modification of the Denis Browne Method and Splint

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From the Hospital for Sick Children, Toronto

During the past nine years many recurrences of congenital club-foot have clouded an earlier optimistic report[1]. These have not dampened our enthusiasm, because an analysis of these cases places the blame entirely upon the parents. Club-foot deformity is limited for the most part to the underprivileged classes, which adds a difficult personal element as far as treatment is concerned. In many of the cases of forthright parental neglect, our Social-Service Department discovered pitiful domestic conditions. In such instances foster homes were obtained, if possible. Failure to repair or replace dilapidated and outgrown apparatus was a common offense. In many of these cases, the families were large and underprivileged; care of the foot at home was often a hardship and, therefore, was not continued. Such parents were frequently ashamed to return to the Clinic. Strangely enough, return visits were made more regularly by those living far away than by those nearby. All these circumstances have prompted us to intensify the Social-Service inspection of the refractory cases. This has been aided by an appointment-card system with a rapid follow-up in case of failure to report.

In spite of the foregoing implications, numerous cases have presented difficulties during the course of treatment. The underlying cause of the trouble usually becomes evident after a few weeks. The most common of these cases are:

1. Mild types of myodystrophia foetalis, limited to the lower extremity and foot. When the extreme adduction has been corrected, a short, small, resistant foot is recognized, in which any correction is very slow and difficult.

2. Another similar type is a foot at first in severe equinovarus, which soon presents the added feature of a primus metatarsus varus. Such a condition may or may not have muscle involvement, but in either case correction is not the usual easy routine.

3. The neurogenic club-foot appears less frequently and shows motor and sensory changes. Occasional cases of this type of club-foot are corrected with amazing rapidity, only to become a potential calcaneovalgus deformity; while others of this type show a persistent tendency to recur. The bifid lumbar spine or the later growth of long fine hair over that area substantiates the diagnosis. Unusually sensitive trophic skin changes also lead to the suspicion of a neurogenic state.

4. Subluxation of the first metatarsophalangeal joint with dorsal displacement of the great toe is uncommon and of little trouble, and can be controlled by a pad under the head of the metatarsal. It usually becomes minimal at the walking stage.

5. A more common difficulty is the idiopathic club-foot of relatively small size, with a very large fat ankle and leg. This condition simply presents the mechanical problem of adhesive fixation over a deeply wrinkled ankle. Suitably placed small gauze pads help to control this type of case.

6. In a few cases an extremely flat foot has developed early in the treatment. In most of these cases, all treatment was stopped, in the hope that recurrence would not take place, but deformities recurred in all but a few instances.

Such examples depict a few irregularities which help to remind us that equinovarus deformities may have many inherent differences. In most cases these defects are difficult to detect at onset and become evident only after a few weeks of treatment. The hip and

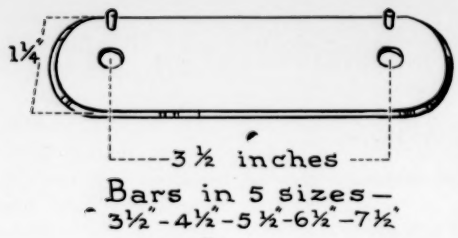

FIG. 1

knee joints must be normal if the splint is to achieve its purpose. Club-foot is an outstanding example of a condition that requires a unified continuity of attention from both surgical and technical staffs, if favorable results are to be obtained. The moment that casual supervision is allowed, recurrences begin to soar.

A few modifications in treatment are worthy of mention:

1. The length of the crossbar has been considerably shortened and now conforms to the distance between the hips (Fig. 1). This was done in order to overcome numerous cases of refractory varus. Additional correction was also obtained in such cases by keeping the foot piece fixed at one hole less than a right angle. In that position, valgus movements, as well as dorsiflexion, may be performed. Bending of the crossbar may occasionally be required in a sick child who does not actively kick or crawl.

2. The foot plates are now made to fit the average foot more snugly. An undersized plate will stay on better than one that is too large. Foot plates are made in four sizes and are covered with sponge rubber. The first three sizes will usually suffice until the boot-splint stage is reached. The plate sizes are shown in Figure 2 before the upright portion has been bent.

3. The boot splints are no longer made to order, because of the time and expense required. A small pair of baby boots are fitted; then the simple adjustments are fastened to a reinforced sole; and the toe cap is removed. Therefore, the child does not reach the boot-splint stage quite so early as formerly, because accurate fitting is difficult in a small foot. The same proportionately short crossbar is used with the boot splints, which are kept on day and night. During the child's second year—the beginning of the walking period—splints are used at night, and are also applied for long periods during the day for exercise. If the foot appears to be essentially normal and no tendency to recurrence is evident, the foregoing regimen may be modified and finally abandoned. If, however, any club-foot stigmata remain—such as limitation of full dorsiflexion or varus—a strict and pro-

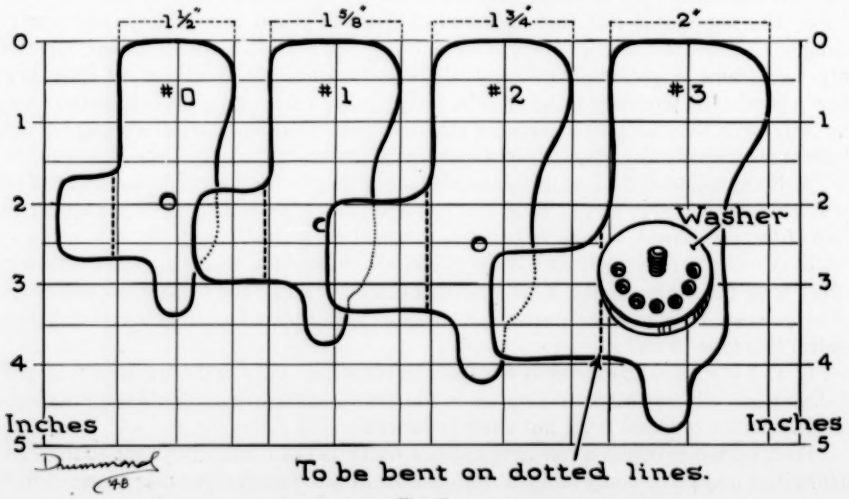

FIG. 2
Foot-plate patterns.

longed application of the boot-splint is recommended, the use of the walking boots being allowed for only a few short periods a day. It may be necessary to continue this care well into the third or fourth year of life. Whenever the boot splints are used, the parents are urged to manipulate the foot daily.

4. The spring splint[2] has been simplified (Fig. 3) by elimination of the adjustable swivel, which occasionally gave trouble when the child was going down steps. This splint has done much to compensate for the negligence of the parent, since it replaces not only the boot splint, but also the need for daily manipulation. It is, therefore, occasionally used on a well-corrected foot, where parental neglect is feared. The usefulness of this splint decreases with the age of the child and is of doubtful value in the average-sized child after seven to eight years of age. Bob-skating, ice-skating, roller-skating, and skiing are urgently prescribed as a daily routine, since these sports all require dorsiflexion.

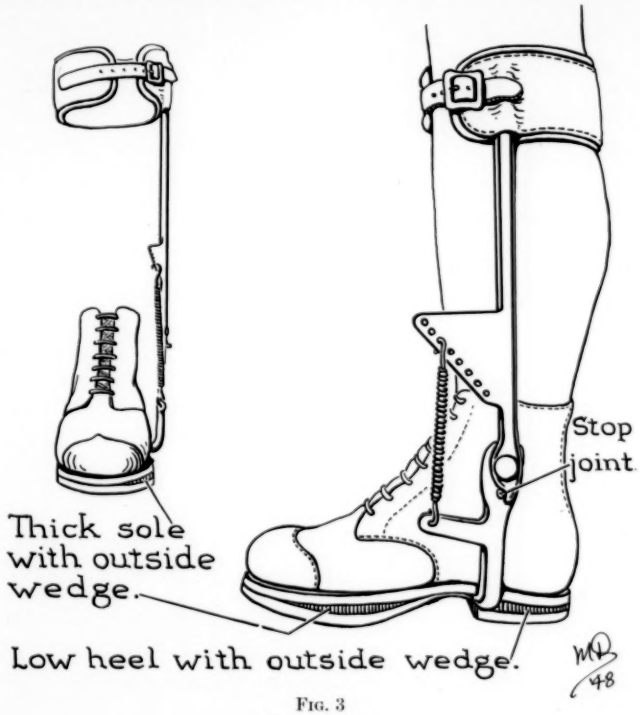

FIG. 3
Spring splint.

Recurrences begin to appear as soon as the parents are asked to share more responsibility in the care of the feet, beginning at the boot-splint stage and increasing at the walking period. Thus, the incidence of good results varies directly with the intelligent cooperation of the parents. Recurrences which limit dorsiflexion to a right angle or better can be controlled and improved by rigid application of the boot splints. However, a recurrence which will not allow passive dorsiflexion of the foot as far as a right angle with the leg will not be amenable to the boot splint. In these cases the Denis Browne splint must again be used, with adhesive fixation. This can be done until about two years of age, but is not very successful after that time, because of pressure effects, due to the combination of a more resistant foot and a more active child. It may then be necessary to resort to manipulation and the application of a plaster cast at one or more sittings. When the recurrence has been partly or fully overcome, the boot splint may be re-applied. In the past two years, it has been deemed wiser to apply the spring splint, because it provides double assurance against these chronically careless parents.

During the past nine years, 260 cases of idiopathic equinovarus deformities have been treated with the Denis Browne splint. We continue to be highly pleased with this method and, by and large, we obtain uniformly good results. The deformity is corrected in six to eight weeks without manipulation, and the foot and leg take on a remarkably normal appearance. In such cases, no recurrence or complication is anticipated, if the doctor and

parent keep their faith and the child remains healthy. If complications arise, they usually become evident during the initial two months of correction, when a revised diagnosis and treatment may be necessary.

During the past two and three-quarters years, since the spring splint has been in use, a better check has been kept on frank recurrences. Forty children in the group have been supplied with spring splints, which represents a recurrence rate of approximately 15.3 per cent. Many of these children had not returned to the Clinic for many months or years, while other recurrences were detected earlier. If the early cases, in children under one year of age, are left out of the total, the recurrence rate is approximately 17 per cent.

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2. Thomson, S. A.: A Splint for Treatment of Recurrent Club-Foot. J. Bone and Joint Surg., **28**: 778–779, Oct. 1946.

UNIVERSAL SPLINT FOR HIP MOTION *

BY PAUL C. THOMPSON, M.D., SWANNANOA, NORTH CAROLINA, AND
JAMES H. CHERRY, M.D., ASHEVILLE, NORTH CAROLINA

From the Division of Orthopaedic Surgery, Swannanoa Division, Veterans Administration Hospital, Oteen, North Carolina

It is generally agreed by most orthopaedic surgeons that the end results of Vitallium-cup arthroplasty depend to a great extent upon the patient's will and determination to regain hip motion following surgery, with the assistance of physical therapy. This fact has led the authors to devise a universal splint for the lower extremity. The apparatus can be easily adjusted to fit all sizes and shapes of limbs, and is of such simplicity that it can be applied or removed within several minutes.

This splint (Figs. 1 and 2) has a knee bend without a lock and a foot piece to which the shoe can easily be attached. The foot piece rests on two rollers, two and one-quarter inches in size, which permit motion in all directions. With the patient in the proper position and a small fracture board in place across the lower third of the bed, the splint can be moved in any direction on the board. By the manipulation of two ropes with pulleys and hand attachments, the patient can secure any form of hip motion. Figure 1 demonstrates the mechanism for securing free ankle and knee motion. Figure 2 shows the limb in abduction, secured by manipulation of hand attachments; the patient can actively bring the limb into abduction.

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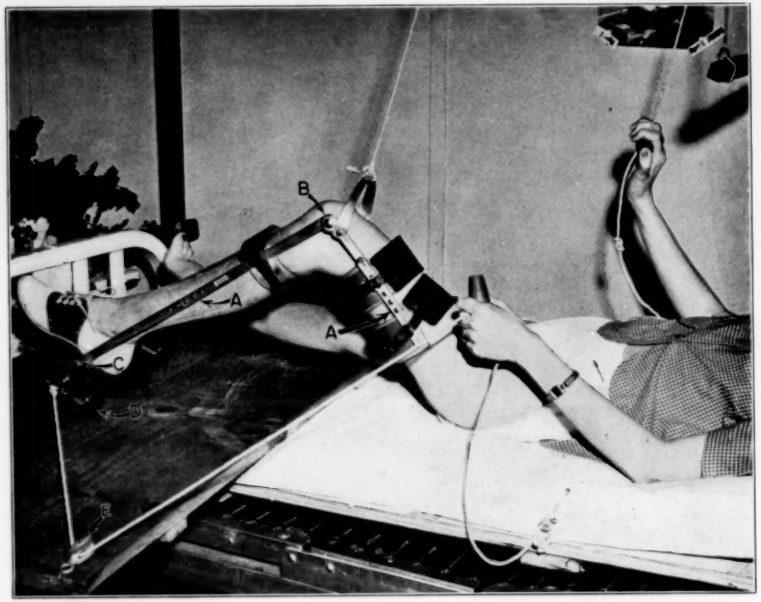

FIG. 1

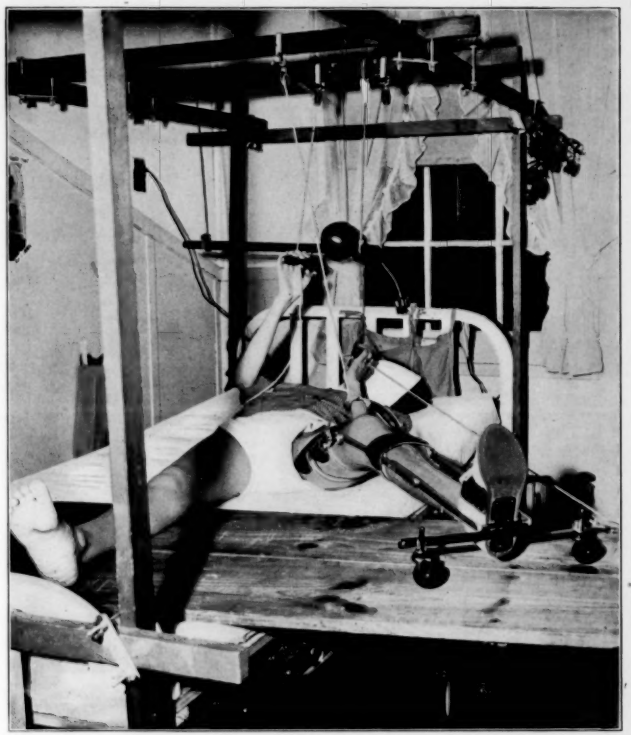

FIG. 2

Fig. 1: Lateral view of universal splint, demonstrating the mechanism for securing free ankle and knee motion.
A: Adjustable length mechanism.
B: Knee bend to permit free knee motion.
C: Caliper plate to afford free ankle motion.
D: Two and one-quarter-inch rollers.
E: Pulley.

Fig. 2: Anterior view shows how, by manipulation of apparatus, patient has brought leg into abduction. Ropes and pulleys can be arranged to obtain lateral and medial motion, as needed.

Postoperative treatment following Vitallium-cup arthroplasty of the hip at this Hospital consists of immobilization in a unilateral hip spica with the lower extremity in abduction and internal rotation for a period of three weeks. Following this, the cast is removed and a universal splint is applied. The splint is worn throughout the day, except for one hour in the morning and another in the afternoon when physical therapy is instituted. At night the splint is removed and Buck's traction, with approximately five pounds of weight, is applied.

The results in this Hospital in regaining hip motion by the use of this universal splint have been excellent. The splint has met with enthusiastic response on the part of the patients, who find that they are able to secure voluntary active and passive motion and to regain a wider range of motion of the affected limb than is possible with other types of mechanotherapy or with physical therapy alone.

NOTE: The authors wish to acknowledge the assistance of Mr. W. A. McElduff, Asheville, North Carolina, in the construction of this splint.

A SPINE RETRACTOR OF SIMPLE CONSTRUCTION

BY WERNER P. JENSEN, M.D., OMAHA, NEBRASKA

The perfect spine retractor has yet to be made. Usually the muscle slips from under the retractor blades, the retractor itself does not remain in place, or the retractor opens only after a great deal of effort.

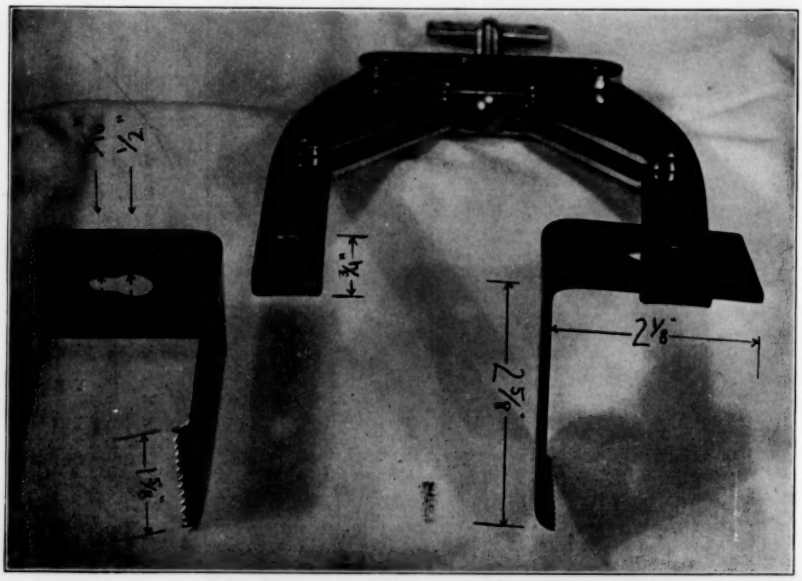

FIG. 1

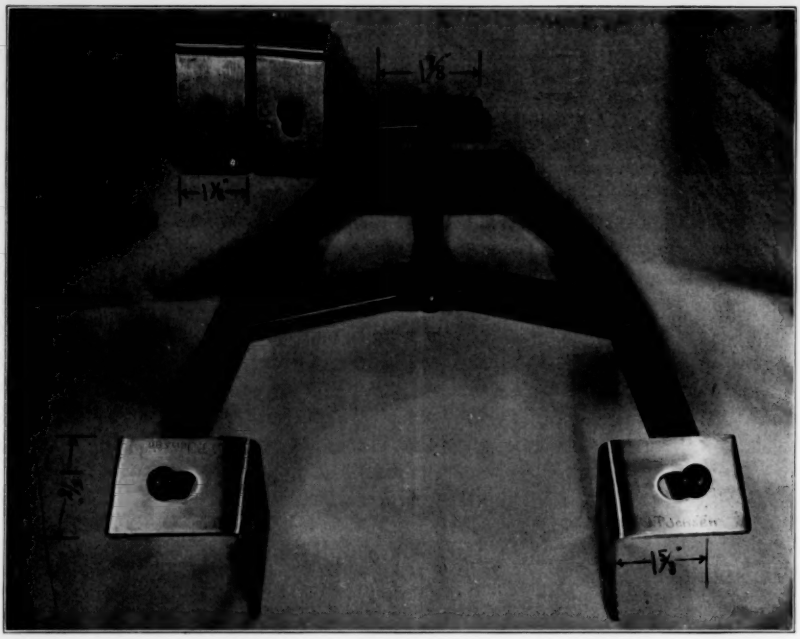

FIG. 2

The retractor pictured (Figs. 1 and 2), when placed in position and opened, holds the spine muscles so that the lamina and articular facets are readily accessible. The motor of the retractor is a medium-sized Kirschner clevis. That pictured was obtained from war-assets surplus. The blades are made of stainless steel, patterned after Hibbs' spine retractors, and have proved satisfactory. The design of the blades may be changed to suit individual requirements. The blades touch when the clevis is closed and may be spread apart to give an opening of five and one-half inches, which is more than is ever required.

In making the retractor, the movable portions of the wire-holding jaws of the clevis were removed and the two ends were made flat by polishing on a grindstone. A five-sixteenths-inch bolt with a half-inch head was then secured, three-quarters of an inch from the end of each arm. The turning handle of the clevis was cut down with a hack saw to one and seven-eighths inches. This permits easy opening of the blades without tilting of the retractor, and ample leverage is still retained.

The blades of the retractor were easily made, with the use of a drill press, vise, hack saw, file, and grindstone. The teeth were cut with a file. The stainless steel bends easily without being heated. The wider blade, of the two pictured, has been used most frequently.

NOTE: Acknowledgment is made to Mr. Earl Rodgers, brace maker at Shriners' Hospital for Crippled Children, Shreveport, Louisiana, for his help and suggestions, and to Wynton H. Carroll, M.D., Senior Resident in Radiology at Charity Hospital, Shreveport, for the photographs.

AN ABDUCTION EXERCISE SPLINT FOR THE SHOULDER

BY EDWARD J. COUGHLIN, JR., M.D., WILLIAMSTOWN, MASSACHUSETTS

In many lesions in and around the shoulder joint, abduction within certain limits is greatly to be desired. Unfortunately, this has not been possible in many instances without keeping the patient confined to bed in some form of balanced suspension. From an economic point of view, this is burdensome; and at the present time, with hospital beds at a premium, it is impossible. In an attempt to provide abduction exercises without hospitalization, the ambulatory splint was devised.

The idea of this splint is not original with the author. A crude abduction apparatus was first seen by the author in a prisoner-of-war camp in southern France. The original splint consisted of a plaster-of-Paris cuirass into which was incorporated a metal U-shaped bar; at the tip of this bar a pulley was attached. The author's first modification was to make the cuirass of castex with laces, so that it could be removed at night; and the splint illustrated here is the final outcome of this modification.

The splint consists of a U-shaped metal bar which is strapped to the body by means

FIG. 1

FIG. 2

of cross straps, and an axillary ring on the opposite side. In addition, there is a shoulder strap on the affected side to prevent the shoulder from being elevated during the period of abduction (Fig. 1). The principle underlying the splint is very simple: Extension of the elbow shortens the rope from the elbow to the pulley (Fig. 2), and by means of the sling around the elbow, the arm is brought into abduction. The degree of abduction to be obtained may be varied by shortening or lengthening the rope extending from the elbow sling to the hand grip.

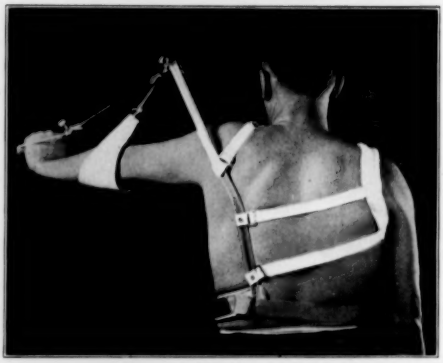

FIG. 3

The use of the abduction exercise splint is especially indicated in the following:

1. *Subdeltoid Bursitis.* The author has used the abduction exercise splint on several patients with acute subdeltoid bursitis, following novocain injection and lavage of the bursa.

2. *Calcification in the Supraspinatus Tendon.* By the use of the abduction exercise splint, the patient with calcification in the supraspinatus tendon is able to be ambulatory immediately after operation and to carry out abduction exercises with little or no discomfort.

3. *Exercise for the "Frozen Shoulder".* The use of this splint will enable immediate active motion through a wide range and with a considerable degree of comfort.

4. *Lesions of the Musculotendinous Cuff.* By means of the active abduction splint, used postoperatively, the arm can be abducted as much as 90 degrees with no danger of disturbing the suture line of the repair of the musculotendinous cuff.

5. *Fractures.* Following impacted fractures or in fractures of the greater tuberosity where graded amounts of abduction are desirable, the splint may be used to encourage motion within a limited range, since by lengthening the abduction cord any degree of abduction desired can be obtained. Of course, the splint should never be used when there is any danger of disimpacting fragments or in shaft fractures where angulation would inevitably occur. It should be used only for patients who would otherwise be receiving relaxing and circumduction exercises.

6. *Nerve Lesions.* The author has used the abduction splint on several cases of axillary-nerve paralysis, following dislocations of the shoulder, with extremely gratifying results. On two occasions, the splint has been used in poliomyelitic patients with involvement of the abduction mechanism. By the use of the abduction splint with resistance, the power of a partially paralyzed deltoid has been increased so that active abduction was possible.

NOTE: The author is indebted to Carl Raminger of the Hospital for Special Surgery, New York, N. Y., for his cooperation in constructing the abduction exercise splint.

A RIGID PLASTIC CORSET FOR ARM AND LEG BRACES

BY LIEUTENANT COLONEL MILTON S. THOMPSON, *Medical Corps, United States Army,*
AND CAPTAIN REX J. HOWARD, *Medical Corps, Army of the United States*

From the Orthopaedic Service, Brooke General Hospital, Fort Sam Houston, Texas

In certain patients with ununited fractures of long bones, delayed union of fractures, loss of bone substance, or old infections of bone, rigid fixation of the extremity is essential to prevent deformity, and ambulation is desirable. Casts and traction will provide the necessary rigidity, but these prevent ambulation. The common type of ischial weight-bearing brace permits ambulation, but it fails to provide the necessary rigidity in some instances. To solve this problem, a brace has been developed which incorporates the

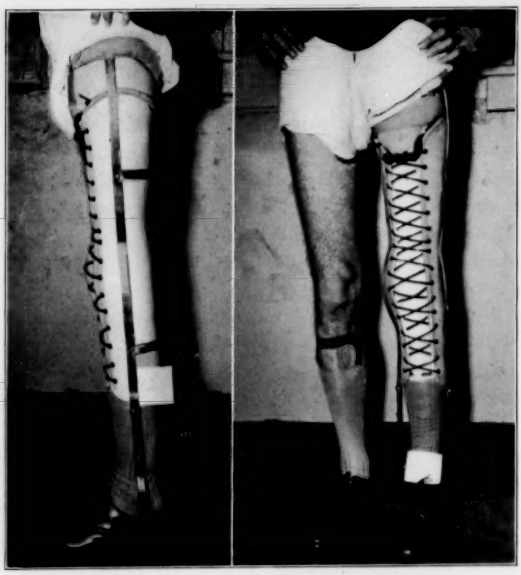

FIG. 1-A FIG. 1-B

Fig. 1-A: Lateral view of corset, incorporated into an ischial weight-bearing brace.
Fig. 1-B: Anterior view of corset and brace.

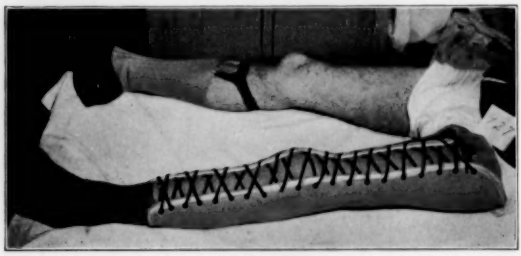

FIG. 2
Corset used as night splint.

rigidity of a plaster cast into a brace and which at the same time enables many of these patients to become ambulatory (Figs. 1-A and 1-B).

A positive plaster mold of the extremity is made. This mold is then covered with horsehide, the edges of which meet anteriorly in a vertical line. The leather is fastened with tacks, and one coat of a cellulose cement, which is soluble in acetone, is applied and allowed to dry for twenty minutes. Then, a piece of celastic, the size of the horsehide cover, is dipped into acetone; when saturated, the celastic becomes completely limp and pliable. The leather is dampened with acetone and the piece of celastic is quickly molded to it, wrapped with an elastic bandage, and allowed to dry for four or five hours. Another piece of horsehide is then placed over the celastic with the cement. This is also allowed to dry for four or five hours. The edges are then trimmed and bound with horsehide. Eyelets are inserted along the anterior gap, approximately one and one-fourth inches apart, and one-half inch back from the edge. Laces are inserted, and the molded splint is complete. This splint may be easily incorporated into a brace (Figs. 1-A and 1-B).

The authors have used celastic in braces for both the lower and upper extremities. Moreover, it is used by the Army in making sockets for artificial limbs. It can also be used in shoulder caps for shoulder disarticulations, in inner soles for partial-foot amputations, in night splints (Fig. 2), and for many other orthopaedic appliances. It is light, strong, easily molded, and highly suitable, therefore, for making snug-fitting splints for the extremities.

NOTE: Acknowledgment for the technical details of this brace is made to Arthur D. Salmon, Chief Orthopaedic Mechanic, Brace Shop, Brooke General Hospital.

A LUMBOSACRAL SUPPORT

BY REX L. DIVELEY, M.D., KANSAS CITY, MISSOURI

It is frequently necessary to provide support to the lumbosacral region or the lower lumbar segments of the spine. This is accomplished relatively simply in female patients by the incorporation of a light steel brace in a properly fitted front-lace corset. In male patients the problem is more difficult, as most low-back braces are uncomfortable to wear and they often fail to give adequate immobilization to the lumbosacral area.

To solve this problem for the male patient, a so-called lumbosacral belt has been developed, which has been used with gratifying results. This belt has proved efficient in the treatment of acute lumbosacral strain or sprain, in lumbosacral arthritis, in the postoperative care of lumbosacral fusion, and, in fact, in any condition in which immobilization of the lumbosacral joint or the lower lumbar spine is desired. This type of belt also gives satisfactory support to a man with a pendulous abdomen.

Our bracemaker carries in stock four sizes of lumbosacral steel frames, seven, eight, nine, and ten inches in height (Fig. 1). The appropriate style of steel frame, which should extend from the body of the sacrum as far up the lumbar spine as immobilization is desired (generally the second or third lumbar vertebra), is selected and carefully fitted to the curve of the back with bending irons (Fig. 2).

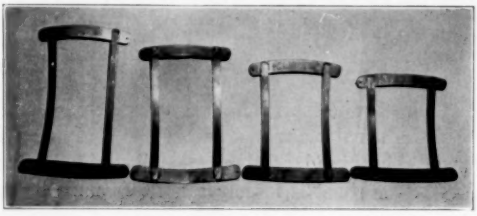

FIG. 1

Steel frames, varying from seven to ten inches in height, for lumbosacral support.

For the female patient, this steel is incorporated into a properly fitted front-lace corset. For the male patient, the steel is fitted into a duck belt which is held in place by three or four straps with buckles. Two additional reinforcing straps attached to the steel, one above and one below, hold the steel firmly against the back (Figs. 3 and 4). This belt will usually stay in place quite satisfactorily, but, if it tends to ride upward, peroneal straps can be added.

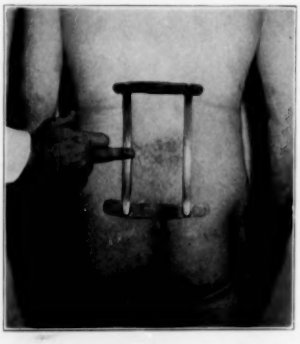

FIG. 2

Brace fitted to curve of back.

FIG. 3 FIG. 4

Front and back views of support, applied to patient.

ADAPTATIONS OF THE SURGICAL ENGINE

BY DANIEL M. STIEFEL, M.D., DETROIT, MICHIGAN

From the Department of Orthopaedic Surgery, Grace Hospital, Detroit

A simple adaptation of the widely used Luck saw or surgical engine has proved useful to the author. It has become increasingly apparent that the dentist's armamentarium contains a number of devices which can be used with good results in orthopaedic surgery. This is especially true of a short drill in a dental handpiece, which can be used in drilling the glenoid rim in the Bankart operation.

To adapt the dental handpiece to this surgical engine, a flexible shaft is used to transmit power to the drill in the dental device. The shaft may be easily attached to the Jacobs chuck of the engine by inserting a short quarter-inch rod into the motor end of the shaft. The tool end of the shaft is furnished with two interchangeable collets with capacities from zero to one-quarter of an inch. The flexible shaft is four feet long, and the handpiece of this shaft is one and one-quarter inches in diameter.

A simple stand for the engine is constructed from a metal plate. To this is attached a cradle of bent bands of steel. Passing over the engine, pieces of so-called "power chain" encased in rubber tubing hold it in place on the cradle. One end of each chain is fixed to an end of each member of the cradle on one side. The other ends of the chains, each bearing a wing nut, are fastened to the opposite sides of the two cradle members. When in use, the cradle stand holds the engine and is placed on a small instrument table. The motor end of the sterile flexible shaft is handed to a nurse, who fastens it into the Jacobs chuck with the key in the usual manner. Neither the engine nor its electrical connections are sterilized when used in this adaptation. A small sterile sheet is thrown over the table and engine, and a fold of the sheet is loosely caught around the proximal end of the shaft with a towel clamp.

The adaptor and driver, which are used to drive a tool in a dental handpiece, are shown in Figure 2. Figure 3 shows the assembled apparatus.

The adaptor is a stainless-steel shell which fits over the distal end of the flexible shaft. This adaptor is held in place by a recessed screw, which pierces the shell near its lower rim and is tightened against the shaft end. The dental handpiece is thrust into the hollow neck of the adaptor and is held in place by tightening the ring nut over the slightly conical end of the slotted neck. The inserted tube is thus grasped by collet action. As an added safe-

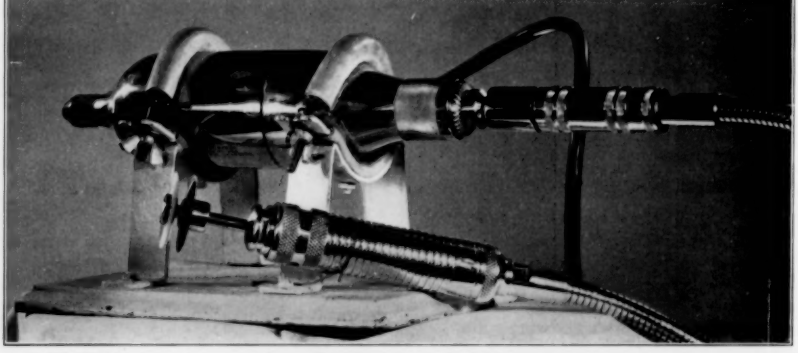

FIG. 1

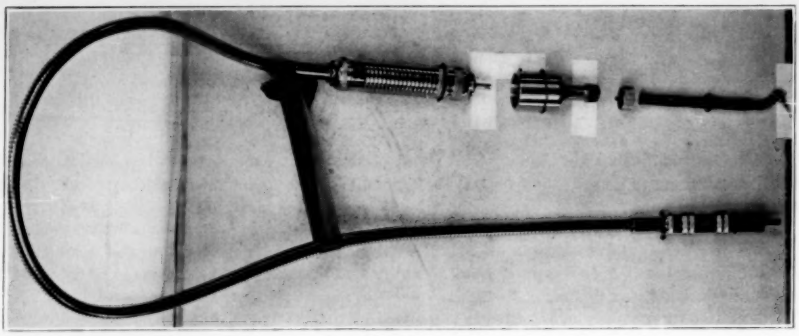

FIG. 2

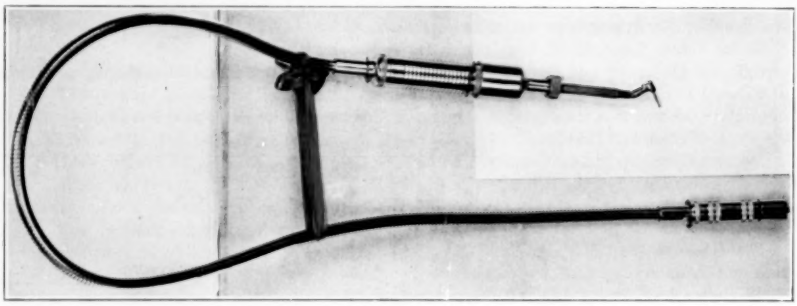

FIG. 3

guard against rotation of the dental handpiece, a recessed screw pierces the adaptor at the base of the neck and enters the slot in the lower end of the handpiece.

The driver of the dental instrument consists of a rod with an inverted notch which, in dental practice, engages with a coupling carrying a similar notched rod in the motor apparatus. In this adaptation, a short length of rod is similarly notched and is furnished with a shoulder, so that it will insert to a constant depth; the rod is then placed in the collet end of the flexible shaft. When the adaptor with its dental handpiece is fitted over the end of the flexible shaft, the two notched rods will readily mesh and power can be transmitted to a tool in the end of the dental device.

All standard dental metallic burrs and tools used with such a handpiece may also be used in surgery. For use in drilling bone for the passage of sutures, the author has had standard 3/32-inch twist drills cut down to lengths of one and of one and five-tenths centimeters, respectively, with the proximal ends appropriately notched to fit into the dental handpiece.

As seen in Figure 1, the shaft can also be used to drive the regular saws and drills usually attached directly to the engine chuck. The engine can easily be taken from its stand for other uses.

NOTE: The writer wishes to acknowledge valuable technical advice and help in the construction of these adaptations given by Mr. Fred Walton of Detroit.

News Notes

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Sixty-second Annual Meeting of The American Orthopaedic Association will be held at the Broadmoor, Colorado Springs, Colorado, on May 18, 19, 20, and 21, 1949, under the presidency of Dr. Ralph K. Ghormley.

The orthopaedic surgeons of Denver, with Dr. Robert G. Packard and Dr. Atha Thomas as chairmen, have planned a Clinical Day in Denver on May 17. All members of the Association and their guests are invited. Those planning to attend are requested to notify Dr. Packard or Dr. Thomas in advance, so that adequate arrangements may be made.

The tentative program of the Meeting, as submitted by the Program Committee, is as follows:

WEDNESDAY, MAY 18

Morning Session

Osteochondromata Arising from Articular Cartilage.
James Vernon Luck, M.D., Los Angeles, California (by invitation).

Correction of Deformity and Prevention of Aseptic Necrosis in Late Cases of Slipped Femoral Epiphysis.
Edward L. Compere, M.D., Chicago, Illinois.

Congenital Dislocation of the Hip with Particular Reference to its Pathogenesis—Treatment by Open Reduction and Results.
Beckett Howorth, M.D., New York, N. Y.

Extra-Articular Fusion of the Hip.
George W. Van Gorder, M.D., Boston, Massachusetts.

A New Technique for Arthrodesis of the Hip.
Alan DeForest Smith, M.D., New York, N. Y.

Trials and Tribulations in Attempted Femoral Lengthening.
H. Relton McCarroll, M.D., St. Louis, Missouri.

Noon: Executive Session.

Afternoon Session

A Conference, sponsored and arranged by the Joint Committee on Postgraduate Education of The American Orthopaedic Association and The American Academy of Orthopaedic Surgeons.

1. Introductory remarks by the Chairman.
   A. R. Shands, Jr., Alfred I. duPont Institute, Wilmington, Delaware.
2. The Ideal Curriculum:
   A. For Adult and Fracture Training.
      Alan DeForest Smith, M.D., New York Orthopaedic Hospital, New York, N. Y.
   B. For Children's Training.
      William T. Green, M.D., Children's Hospital, Boston, Massachusetts.
   C. For Basic-Science Instruction.
      Guy A. Caldwell, M.D., Tulane University, New Orleans, Louisiana.
3. The Ideal Curriculum of Resident Training in:
   A. A University Clinic.
      Carl E. Badgley, M.D., University of Michigan, Ann Arbor, Michigan.
   B. A Private Clinic.
      J. Spencer Speed, M.D., Campbell Clinic, Memphis, Tennessee.
4. Resident Training in a Government Hospital:
   A. Veterans Administration.
      Dana M. Street, M.D., Kennedy Veterans Hospital, Memphis, Tennessee.
   B. United States Army.
      Lieutenant Colonel Milton S. Thompson, M.C., Brooke General Hospital, Fort Sam Houston, Texas.
5. Special Training the Resident Should Have in:
   A. Cerebral Palsy.
      Robert A. Knight, M.D., Campbell Clinic, Memphis, Tennessee.
   B. Infantile Paralysis.
      R. E. Lenhard, M.D., Johns Hopkins Hospital, Baltimore, Maryland.
   C. The Fitting and Making of Braces and Prostheses.
      Atha Thomas, M.D., Denver, Colorado.

6. Special Training the Resident Should Have in:
   A. Related Subjects: Physical Medicine, Roentgenology, Neurology, and Rheumatology.
   B. Research and Publications.
   Fremont A. Chandler, M.D., University of Illinois, Chicago, Illinois.
7. The Graduate School of Medicine Course in Orthopaedic Surgery and Its Curriculum.
   J. T. Nicholson, M.D., University of Pennsylvania Graduate School, Philadelphia, Pennsylvania.
8. What Constitutes a Satisfactory Preceptorship Training.
   J. Albert Key, M.D., Washington University, St. Louis, Missouri.
9. Comments from The American Board of Orthopaedic Surgery on Board Certification and Resident Training.
   Francis M. McKeever, M.D., Los Angeles, California.
10. The American College of Surgeons and Specialty Training.
    P. D. Wilson, M.D., The Hospital for Special Surgery, New York, N. Y.
11. The American Medical Association and Specialty Training.
    F. H. Arestad, M.D., Council on Medical Education and Hospitals, Chicago, Illinois.
12. Discussion and Summary.

THURSDAY, MAY 19

Morning Session

The Orthopaedic Treatment of Tuberculosis of the Spine in a Military Tuberculosis Center.
Lieutenant Colonel Harold S. McBurney, Denver, Colorado (by invitation).

Fusion of the Shoulder Joint in Children, Utilizing Autogenous Bone Graft.
Charles R. Rountree, M.D., Oklahoma City, Oklahoma.

Conclusions Concerning the Use of Refrigerated Bone in Orthopaedic Surgery.
Philip D. Wilson, M.D., New York, N. Y.

Treatment of Sclerotic or Aseptic Non-Union of the Tibia with an Associated Intact or Healed Fibula.
Carl E. Badgley, M.D., Ann Arbor, Michigan.

Correlation of Myelographic and Operative Findings in Intervertebral-Disc Lesions.
J. Albert Key, M.D., St. Louis, Missouri.

Cauda Equina Tumors as a Cause of the Low-Back Sciatic Syndrome.
James W. Toumey, M.D., Boston, Massachusetts.

FRIDAY, MAY 20

Morning Session

Restriction of Growth of Bone by Pins through the Epiphyseal Cartilage Plate.
Sylvan L. Haas, M.D., San Francisco, California.

Acute Non-Tuberculous Psoas Abscess.
Isadore Zadek, M.D., New York, N. Y.

Giant-Cell Tumors in Children.
Harold D. Palmer, M.D., Denver, Colorado (by invitation).

Factors which Influence Survival in Bone Sarcoma.
C. Howard Hatcher, M.D., Chicago, Illinois.

The Effects of Radio-Activity on Bone.
John Z. Bowers, M.D., Washington, D. C. (by invitation).

Presidential Address.
Ralph K. Ghormley, M.D., Rochester, Minnesota.

SATURDAY, MAY 21

Morning Session

Congenital Metatarsus Varus.
J. Hiram Kite, M.D., Atlanta, Georgia.

A Study of a Large Series of Keller Operations Performed for Hallux Valgus.
Mather Cleveland, M.D., New York, N. Y.

Ski Injuries—Trauma of Lower Extremities Resulting from Torsion Strain.
John R. Moritz, M.D., Sun Valley, Idaho (by invitation).

Chondromalacia of the Patella: Early Manifestations and Late Results, Diagnosis, and Treatment.
Edwin F. Cave, M.D., Boston, Massachusetts.

Circulatory Changes in the Extremities, Associated with Infantile Paralysis and the Relation to the Occurrence of Shortening.
William T. Green, M.D., Boston, Massachusetts.

Noon: Final Executive Session.

By invitation of **The British Orthopaedic Association,** a group of orthopaedic surgeons, chosen by The American Orthopaedic Association, are visiting orthopaedic centers in England and Scotland.

The group, representing ten different sections of the country, are:

Lee Ramsay Straub, M.D., New York, N. Y.;
Carroll B. Larson, M.D., Boston, Massachusetts;
John Hamilton Allan, M.D., Philadelphia, Pennsylvania;
Hugh Smith, M.D., Memphis, Tennessee;
S. Benjamin Fowler, M.D., Nashville, Tennessee;
Benjamin E. Obletz, M.D., Buffalo, New York;
John J. Fahey, M.D., Chicago, Illinois;
William H. Bickel, M.D., Rochester, Minnesota;
Verne T. Inman, M.D., San Francisco, California;
Donald W. Blanche, M.D., Los Angeles, California.

With a similar group from The Canadian Orthopaedic Association, these men gathered in New York on March 16 for a Clinical Day arranged at some of the New York hospitals, followed by a farewell dinner given at the Harvard Club in New York.

They sailed on March 17 and, after a week in London, will visit various other orthopaedic centers. They will attend the Spring Meeting of The British Orthopaedic Association, to be held in Nottingham the last of April under the presidency of Mr. S. Alan S. Malkin. They will return before the Annual Meeting of The American Orthopaedic Association, to be held in Colorado Springs May 18 through 21.

This unusual opportunity has been made available to these men through the generosity of The British Orthopaedic Association.

The Executive Board of the **American Public Health Association** announces that the Seventy-seventh Annual Meeting of the Association and meetings of related organizations will take place in New York City, October 24 to 28. The Hotels Statler and New Yorker are joint headquarters.

The Alumni of the **Hospital for Joint Diseases,** New York City, will conduct an Orthopaedic Conference from May 12 through May 14. On the evening of May 12, Dr. C. Howard Hatcher of Chicago will deliver the Sir Robert Jones Lecture at the Hospital on "The Results of Treatment of Bone Sarcoma". All those interested are invited to attend.

The Sixty-first Annual Meeting of the **American Association of Railway Surgeons** will be held at the Drake Hotel, Chicago, on June 30, July 1, and the morning of July 2, 1949.

Dr. M. N. Smith-Petersen of Boston has recently been honored by election to honorary membership in the Royal Medical Society of Edinburgh.

Dr. Donald E. King has been appointed Professor of Bone and Joint Surgery at Stanford University.

The **National Society for Crippled Children and Adults, Inc.,** has recently conducted the annual sale of Easter seals for the support of its work.

Recently this Society, through its Executive Director, Lawrence J. Linck, awarded eight scholarships to physicians, surgeons, and physical therapists for specialized training in cerebral palsy. The scholarships were made possible by Alpha Chi Omega, national women's sorority. They cover study at the Children's Rehabilitation Institute, Cockeysville, Maryland, under the supervision of Dr. Winthrop M. Phelps, President of the American Academy for Cerebral Palsy.

The **Sociedad Mexicana de Ortopedia,** founded in 1944, announces the election of the following officers for 1949: Luis Garcia Figueroa, M.D., President; J. J. Domínguez, M.D., Treasurer; and Lasislao Solares, M.D., Secretary.

Dr. Arthur Steindler of Iowa City and Dr. Guy A. Caldwell of New Orleans have been made honorary members of this organization.

The **American Board for Certification of the Prosthetic and Orthopaedic Appliance Industry, Inc.,** has been established, with headquarters in Washington, D. C. The purpose of the Board is to improve professional standards of manufacturers of artificial limbs and braces.

Three orthopaedic surgeons and four leaders in the orthopaedic-appliance industry constitute the group which will grant certification. The orthopaedic surgeons are: Dr. Rufus Alldredge, New Orleans, Louisiana; Dr. Henry H. Kessler, Newark, New Jersey; and Dr. Atha Thomas, Denver, Colorado. Lay members are Chester C. Haddan, Denver, Colorado; Lee J. Fawver, Kansas City, Missouri; J. B. Korrady, Chicago, Illinois; and David E. Stolpe, New York, N. Y. Mr. Haddan is President and Glenn E. Jackson, Washington, D. C., is Executive Director.

An agreement of affiliation between the **New York Hospital** and the **Hospital for Special Surgery** has been announced jointly by William H. Jackson, President of the Society of the New York Hospital, and Samuel S. Duryee, President of the New York Society for the Relief of the Ruptured and Crippled. This affiliation, which has the approval of the Hospital Council of Greater New York and is subject to the approval of the Court, calls for the erection by the New York Society for the Relief of the Ruptured and Crippled of a new hospital of approximately 170 beds for orthopaedic and arthritic patients on land on the East River Drive between 70th and 71st Streets. This land, which is now owned by the New York Hospital, will be transferred by it without monetary consideration to the Hospital for Special Surgery.

Although the hospitals will continue as independent corporations, meeting their own operating costs and expenses, each will avail itself of the experience and facilities of the other. General surgery and internal medicine (other than treatment of arthritis) will be conducted in the New York Hospital; and orthopaedic surgery and treatment of arthritis, in the Hospital for Special Surgery. Upon the opening of the new hospital, Dr. Philip D. Wilson, the present Surgeon-in-Chief of the Hospital for Special Surgery, will assume the title of Director of Orthopaedic Surgery. Dr. Frank Glenn is the Surgeon-in-Chief of the New York Hospital and the Professor of Surgery of Cornell University Medical College.

This affiliation brings close together two of the oldest and best known of New York's hospitals. The Society of the New York Hospital, created by royal charter dated June 13, 1771, has maintained a general hospital for 178 years. It was the city's first hospital, originally located on Broadway near Duane and Worth Streets. In 1927, the agreement with Cornell University brought about the creation of the present New York Hospital–Cornell Medical Center on York Avenue at East 68th Street.

The New York Society for the Relief of the Ruptured and Crippled has maintained a hospital in New York City since 1863. For years, the old Hospital for the Ruptured and Crippled was on the site now occupied by the Hotel Commodore. Its present Hospital for Special Surgery is on East 42nd Street between First and Second Avenues, and its services and facilities pertain particularly to the care and treatment of patients afflicted with crippling conditions and deformities of an orthopaedic nature, arthritis, and hernia. Programs of teaching and research are also conducted.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Sixteenth Annual Convention of The American Academy of Orthopaedic Surgeons was held at the Palmer House, Chicago, January 22 to 27, 1949, under the presidency of Dr. Myron O. Henry. Total registration at the meeting was 1,975. The Audio-Visual Program and Instructional Courses, under the chairmanship of Dr. Charles N. Pease, were well attended.

On Monday afternoon the new members were presented with their diplomas, following which Dr. Henry gave his Presidential Address. The remainder of the afternoon was devoted to the first Executive Session. A roster of the new members is as follows:

Seymour M. Albert, M.D., Philadelphia, Pennsylvania
Harold Altman, M.D., New York, N. Y.
Moss M. Bannerman, M.D., Baton Rouge, Louisiana
Robert John Bannow, M.D., Pontiac, Michigan
Jurgens H. Bauer, M.D., Syracuse, New York

Thomas Beath, M.D., Richmond, Virginia
Charles O. Bechtol, M.D., Oakland, California
Roderick E. Begg, M.D., Portland, Oregon
George D. B. Berkett, M.D., New Orleans, Louisiana
George A. Berkheimer, M.D., Harrisburg, Pennsylvania
Emanuel Blumenfield, M.D., New York, N. Y.
Gwernydd Newton Boice, M.D., McKeesport, Pennsylvania
Francis N. Brill, M.D., Springfield, Illinois
Joseph Edmund Brown, M.D., Cleveland, Ohio
Robert Clifton Brown, M.D., Neenah, Wisconsin
Everett I. Bugg, Jr., M.D., Durham, North Carolina
Ernest M. Burgess, M.D., Seattle, Washington
Reynoldson Duke Butterworth, M.D., Richmond, Virginia
Irvin Cahen, M.D., New Orleans, Louisiana
Peter Louis Carnesale, M.D., Milwaukee, Wisconsin
Carl G. Caspers, M.D., Minneapolis, Minnesota
Harold M. Childress, M.D., Jamestown, New York
Kenneth Christophe, M.D., Brookline, Massachusetts
Roy C. Ciccone, M.D., Bloomfield, New Jersey
Beverley Boyden Clary, M.D., Richmond, Virginia
Paul J. Collopy, M.D., Milwaukee, Wisconsin
Kenneth L. Cooley, M.D., Rochester, New York
Frederick C. Courten, M.D., Richmond Hill, New York
Robert R. Crawford, M.D., Mansfield, Ohio
John J. Cushner, M.D., York, Pennsylvania
A. J. Day, M.D., Detroit, Michigan
Allan Montague Ferry, M.D., Washington, D. C.
David Leonard Filtzer, M.D., Baltimore, Maryland
Samuel Emory Flook, M.D., Dayton, Ohio
William Porter Forcade, M.D., San Francisco, California
Dale E. Fox, M.D., Cincinnati, Ohio
Clarence LeRoy Francisco, M.D., Kansas City, Kansas
Russell Victor Fuldner, M.D., New Haven, Connecticut
Maurice Gershman, M.D., Far Rockaway, New York
Arthur L. Glassman, M.D., Houston, Texas
C. Fred Goeringer, M.D., Philadelphia, Pennsylvania
James Thomas Green, Jr., M.D., Columbia, South Carolina
Edward D. Hagerty, M.D., Manchester, New Hampshire
Harold T. Hansen, M.D., South Orange, New Jersey
Kenneth J. Harmon, M.D., Niagara Falls, New York
Joel Hartley, M.D., New York, N. Y.
Henry Monroe Hills, Jr., M.D., Charleston, West Virginia
William Vincent Hindle, M.D., Providence, Rhode Island
Edward Charles Holscher, M.D., St. Louis, Missouri
Carl E. Horn, M.D., Sacramento, California
William Templeton Howard, M.D., Memphis, Tennessee
Denman Carter Hucherson, M.D., Houston, Texas
John T. Jacobs, M.D., Denver, Colorado
Floyd H. Jergesen, M.D., San Francisco, California
Herman Joffe, M.D., Chicago, Illinois
Orville Noble Jones, M.D., Portland, Oregon
Elias Noah Kaiser, M.D., Montgomery, Alabama
Robert Patton Kelly, Jr., M.D., Emory University, Georgia
Richard Hotchkiss Kiene, M.D., Kansas City, Missouri
David J. King, M.D., Wilmington, Delaware
Barnard Kleiger, M.D., New York, N. Y.
Marvin Pierce Knight, M.D., Dallas, Texas
Harold H. Kuhn, M.D., Charleston, West Virginia
Kenton D. Leatherman, M.D., Louisville, Kentucky
Harry Linwood Leavitt, M.D., Seattle, Washington
Samuel Levine, M.D., Lynn, Massachusetts
John Lyford, III, M.D., Louisville, Kentucky
James M. McBride, M.D., Lima, Ohio

John O'D. McCabe, M.D., Milwaukee, Wisconsin
Richard M. Mellen, M.D., Colorado Springs, Colorado
Donald Irwin Minnig, M.D., Akron, Ohio
Edwin Leslie Mollin, M.D., Akron, Ohio
Donald E. Moore, M.D., Eugene, Oregon
Joseph Mahon Moore, M.D., Vicksburg, Mississippi
Robert Dunham Moore, M.D., Chicago, Illinois
Donald M. Norquist, M.D., Pasadena, California
Leon Ocel Parker, M.D., San Francisco, California
Paul A. Pemberton, M.D., Salt Lake City, Utah
Homer C. Pheasant, M.D., Los Angeles, California
Anthony J. Pisani, M.D., New York, N. Y.
David Poverman, M.D., New Haven, Connecticut
Willis Law Pugh, M.D., Evansville, Indiana
Irving Redler, M.D., New Orleans, Louisiana
Joseph M. Regan, M.D., Milwaukee, Wisconsin
John Gilbert Reid, M.D., Detroit, Michigan
J. Antonio Samson, M.D., Montreal, Canada
Walter William Schwartz, M.D., Chicago, Illinois
John R. Schwartzmann, M.D., Tucson, Arizona
William Bostwick Sheppard, M.D., Oakland, California
Mary Stults Sherman, M.D., Chicago, Illinois
Stewart W. Shimonek, M.D., St. Paul, Minnesota
Carroll Mitchell Silver, M.D., Providence, Rhode Island
Lyman Smith, M.D., Elgin, Illinois
Donald Ellsworth Starr, M.D., Vancouver, Canada
Richard Carl Stauffer, M.D., Fort Wayne, Indiana
Raymond Oscar Stein, M.D., Philadelphia, Pennsylvania
Marcus Jefferson Stewart, M.D., Memphis, Tennessee
Thomas D. Thompson, M.D., Spokane, Washington
Arthur Stanley Thurm, M.D., Trenton, New Jersey
Eulyss Robert Troxler, M.D., Greensboro, North Carolina
Frank G. Vieira, M.D., Stockton, California
Chester W. Waters, M.D., Omaha, Nebraska
Melvin Brent Watkins, M.D., New York, N. Y.
Heins Wichman, M.D., Jersey City, New Jersey
Paul G. Wiesenfeld, M.D., Perth Amboy, New Jersey
Milton Jay Wilder, M.D., Baltimore, Maryland
Charles H. Wilson, M.D., Birmingham, Alabama
John Curtis Wolgamot, M.D., Great Falls, Montana
William V. Woods, M.D., Indianapolis, Indiana
Robert Montimer Wray, M.D., Cedar Rapids, Iowa
Peter B. Wright, M.D., Augusta, Georgia

Elected to Honorary Membership was:

Albert B. Ferguson, M.D., Boston, Massachusetts

The scientific program was held on Tuesday, Wednesday, and Thursday.

TUESDAY, JANUARY 25

Morning Session

Progressive-Resistance Exercises in Orthopaedics.
Thomas L. DeLorme, M.D., Boston, Massachusetts (by invitation).
Discussion: Philip Lewin, M.D., Chicago, Illinois;
Francis E. West, M.D., San Diego, California.

Electromyography in Orthopaedics.
Arthur L. Watkins, M.D., Boston, Massachusetts (by invitation).
Discussion: Joseph E. Markee, M.D., Durham, North Carolina (by invitation);
R. Plato Schwartz, M.D., Rochester, New York.

The Circulation in Foetal and Infant Spines and Its Probable Influence on Spinal Degeneration.
W. Roland Ferguson, M.D., Baltimore, Maryland (by invitation).
Discussion: Joseph S. Barr, M.D., Boston, Massachusetts;
J. Albert Key, M.D., St. Louis, Missouri.

Pott's Paraplegia.
George J. Garceau, M.D., and Thomas Brady, M.D. (by invitation), Indianapolis, Indiana.
Discussion: Mather Cleveland, M.D., New York, N. Y.;
J. Hiram Kite, M.D., Atlanta, Georgia.

Streptomycin in Tuberculous Bone and Joint Lesions Complicated with Mixed Infection and Sinuses.
David M. Bosworth, M.D.; Alfonso Della Pietra, M.D. (by invitation); and Richard Farrell, M.D. (by invitation), New York, N. Y.
Discussion: Frederick L. Lieboldt, M.D., New York, N. Y.;
John R. Norcross, M.D., Chicago, Illinois.

Afternoon Session

The Influence of the Contact Compression Factor on the Osteogenesis of Surgical Fractures.
G. W. N. Eggers, M.D.; Thomas Shindler, M.D. (by invitation); and Charles M. Pomerat, Ph.D. (by invitation), Galveston, Texas.
Discussion: Hugh Smith, M.D., Memphis, Tennessee;
Edward L. Compere, M.D., Chicago, Illinois.

The Relation of Atomic Emergy to Clinical Medicine.
John Z. Bowers, M.D., Washington, D. C. (by invitation).

Stabilizing Operations on the Foot—A Study of the Indications, Techniques Used, and End Results.
Robert L. Patterson, Jr., M.D.; Frank F. Parrish, M.D. (by invitation); and Elwood N. Hathaway, M.D. (by invitation), New York, N. Y.

Progressive Muscular Atrophy of the Peroneal Type (Charcot-Marie-Tooth). Orthopaedic Management and End-Result Study.
Julian E. Jacobs, M.D., Charlotte, North Carolina, and Commander Chalmers Carr, M.C., Oakland, California (by invitation).
Discussion: W. M. Roberts, M.D., Gastonia, North Carolina.

WEDNESDAY, JANUARY 26

Morning Session

A Clinical Evaluation of the Merthiolate Bone Bank. A Preliminary Report.
Fred C. Reynolds, M.D., and David Oliver, M.D. (by invitation), St. Louis, Missouri.

Experiences in the Use of Homogenous (Bone Bank) Bone.
James B. Weaver, M.D., Kansas City, Kansas.
Discussion: Alberto Inclan, M.D., Havana, Cuba;
P. D. Wilson, M.D., New York, N. Y.

Andry and the Orthopaedia.
R. Beverly Raney, M.D., Durham, North Carolina.

Fixed Osteotomy in the Treatment of Non-Unions of the Neck of the Femur.
John H. Moe, M.D., and Harry B. Hall, M.D., Minneapolis, Minnesota.
Discussion: James A. Dickson, M.D., Cleveland, Ohio;
Henry Milch, M.D., New York, N. Y.

End-Result Study of Arthrodesis of the Hip Joint.
Frank E. Stinchfield, M.D., and William U. Cavallaro, M.D. (by invitation), New York, N. Y.
Discussion: M. N. Smith-Petersen, M.D., Boston, Massachusetts;
Rudolph S. Reich, M.D., Cleveland, Ohio.

Afternoon Session

Prediction of Unequal Growth in the Lower Extremities in Anterior Poliomyelitis.
Allan J. Stinchfield, M.D. (by invitation); J. A. Reidy, M.D.; and Joseph S. Barr, M.D., Boston, Massachusetts.

Controlled Bone Growth by Epiphyseal Stapling. Preliminary Report.
Walter P. Blount, M.D., and George R. Clarke, M.D. (by invitation), Milwaukee, Wisconsin.
Discussion: William T. Green, M.D., Boston, Massachusetts;
J. Warren White, M.D., Greenville, South Carolina.

The Mechanism of the Structural Changes in Scoliosis.
Alvin M. Arkin, M.D., New York, N. Y.
Discussion: Henry F. Ullrich, M.D., Baltimore, Maryland;
Joseph C. Risser, M.D., Pasadena, California.

The Mechanism of Endosteal New-Bone Formation in Estrogen-Treated Mice.
Marshall R. Urist, M.D. (by invitation); Ann Marie Budy, B.S. (by invitation); and Franklin C. McLean, M.D. (by invitation), Chicago, Illinois.
Discussion: A. R. Shands, Jr., M.D., Wilmington, Delaware;
Robert W. Johnson, M.D., Baltimore, Maryland.

THURSDAY, JANUARY 27

Morning Session

Causes for Amputations Performed at Walter Reed General Hospital in Years 1947 and 1948.
Lieutenant Colonel Lloyd W. Taylor, M.C. (by invitation), and Colonel August W. Spittler, M.C. (by invitation), Washington, D. C.
Discussion: Rufus H. Alldredge, M.D., New Orleans, Louisiana;
Francis M. McKeever, M.D., Los Angeles, California;
Mather Cleveland, M.D., New York, N. Y.

Fractures of Both Bones of the Forearm in Adults.
Robert A. Knight, M.D., and George D. Purvis, M.D. (by invitation), Memphis, Tennessee.
Discussion: Walter G. Stuck, M.D., San Antonio, Texas;
D. B. Slocum, M.D., Eugene, Oregon.

Transplantation of the External Oblique Muscle for Abductor Paralysis.
Lowell Thomas, M.D., Indianapolis, Indiana (by invitation); T. Campbell Thompson, M.D., New York, N. Y.; and L. Ramsay Straub, M.D., New York, N. Y.
Discussion: Frank D. Dickson, M.D., Kansas City, Missouri;
Leo Mayer, M.D., New York, N. Y.

Pseudarthrosis Following Operation for Spinal Fusion.
Edgar L. Ralston, M.D., Philadelphia, Pennsylvania (by invitation); Walter A. L. Thompson, M.D., New York, N. Y. (by invitation); and Alan D. Smith, M.D., New York, N. Y.
Discussion: Joseph A. Freiberg, M.D., Cincinnati, Ohio;
Fremont A. Chandler, M.D., Chicago, Illinois.

At the Instructional Course dinner on Saturday night, an "Information Please" program was presented, which was both instructive and entertaining.

The Annual Dinner was held on Wednesday evening. After appropriate introduction by President Henry of the men seated at the head table, a short, informal talk was given by Mr. H. A. Brittain.

The second Executive Session was held at 12:30 P.M. on Thursday, at which time the awards listed herewith were announced. The presidential medallion was presented to Dr. Myron O. Henry by the past President, Dr. Rex L. Diveley. The gavel was presented to the new President, Dr. Mather Cleveland, by the retiring President, Dr. Henry. Following a short acceptance speech by Dr. Cleveland, the meeting was adjourned.

The following awards were made by the Committee on Scientific Investigation:

Class I: Originality in Research Problems.

Award: William Cooper, M.D., New York Hospital for Special Surgery, "Aseptic Necrosis of the Femoral Head in Adults".

Honorable Mention: Henry W. Meyerding, M.D., Mayo Clinic, Rochester, Minnesota, "Benign and Malignant Giant-Cell Tumors of Bone".

Honorable Mention: Carl E. Badgley, M.D., University of Michigan School of Medicine, Ann Arbor, "Ehlers-Danlos Syndrome".

Class II: Scientific Importance and Information.

Award: G. W. N. Eggers, M.D., and T. O. Shindler, M.D., University of Texas School of Medicine, Galveston, "The Influence of the Contact Compression Factor on the Osteogenesis of Surgical Fractures".

Honorable Mention: Robert Lee Patterson, Jr., M.D., Frank F. Parrish, M.D., and Elwood N. Hathaway, M.D., New York Hospital for Special Surgery, "Stabilization Operations on the Foot".

Honorable Mention: Irvin Stein, M.D., and Raymond O. Stein, M.D., Philadelphia, Pennsylvania, "Chemistry of Bone Lesions".

Class III: Clinical Value.

Award: Walter P. Blount, M.D., Donald W. McCormick, M.D., and George Clarke, M.D., Milwaukee Children's Hospital, Milwaukee, Wisconsin, "Temporary Arrest of Longitudinal Bone Growth by Epiphyseal Stapling".

Honorable Mention: David M. Bosworth, M.D., Alfonso Della Pietra, M.D., and Richard Farrell, M.D., New York, N. Y., "Streptomycin in the Treatment of Joint Tuberculosis with Mixed Infection".

Honorable Mention: Fred C. Reynolds, M.D., and David R. Oliver, M.D., Washington University School of Medicine, St. Louis, Missouri, "Merthiolate Bone Bank".

The following awards were made by the Committee on Audio-Visual Education:

Gold Medal: Herbert N. Coleman, M.D., Toronto, Canada, "Surgery of the Knee Joint".

Certificate of Merit: Armin Klein, M.D., Robert J. Joplin, M.D., John A. Reidy, M.D., and Joseph Hanelin, M.D., Boston, Massachusetts, "Slipped Capital Femoral Epiphysis".

Certificate of Merit: David M. Bosworth, M.D., Richard Farrell, M.D., and Alfonso Della Pietra, M.D., New York, N. Y., "Tuberculosis of Joints Following Use of Streptomycin".

Honorable Mention: Lyon K. Loomis, M.D., New Orleans, Louisiana, "Stenosing Tenosynovitis at Radial Styloid Process".

Honorable Mention: Benjamin Fowler, M.D., Nashville, Tennessee, "Intramedullary Fixation of the Femur".

The following awards were made by the Committee on Gadgets:

Duncan C. McKeever, M.D., Houston, Texas, "Disposable Towel Clips".

Donald B. Slocum, M.D., and Donald E. Moore, M.D., Eugene, Oregon, "A Method of Back Strapping".

Hugh T. Jones, M.D., Los Angeles, California, "Pedangle Back Rest".

The Seventeenth Annual Convention will be held at the Waldorf-Astoria, New York City, February 11 to 16, 1950, under the presidency of Dr. Mather Cleveland.

COMPTON RIELY

1872–1948

Dr. Compton Riely of Baltimore died in Martinsburg, West Virginia, on July 27, 1948, at the age of seventy-six. Born in Summit Point, West Virginia, he received his medical education at the University of Maryland, where he was graduated in 1897. For many years he was connected with the division of orthopaedic surgery at his alma mater and held the rank of clinical professor.

In addition, he was certified as a specialist by The American Board of Orthopaedic Surgery, was a fellow of the American Medical Association, and a member of The American Orthopaedic Association. He was affiliated with the Cambridge-Maryland Hospital and the University and Franklin Square Hospitals of Baltimore. He was also attending surgeon on the staff of the King's Daughters' Hospital in Martinsburg.

The death of Dr. Riely marks the passing of one of a group of surgeons, of whom only a few remain, who helped bridge the gap between the older conservatism and the brilliant surgical aggressiveness of modern orthopaedic treatment. He brought the benefits of his specialty to the remoter parts of Maryland and West Virginia, years before the introduction of more elaborate and systematic care of the crippled, first by voluntary organizations, later by state and federal agencies. He was a determined individualist and often it was difficult to convince him that methods other than his own had merit. In the main, he employed non-operative means whenever possible and relied to a great extent upon splints, braces, and casts. In the field of immobilization he was adept. A cast was applied with meticulous and time-consuming care, but finally there emerged an efficient and handsome support. He had great confidence in the healing power of prolonged rest, convinced that nature, if given ample opportunity, wrought the desired result. His methods doubtless brought comfort and relief to many who came under his care.

ARTHUR G. DAVIS

1887–1949

On February 20, 1949, Arthur G. Davis died, at a time when he was at the height of his professional career and was actively engaged in conducting a large private practice and in caring for the crippled poor in his community. With his passing, orthopaedic surgery has lost one of its most energetic and original thinkers and northwestern Pennsylvania has lost the man who pioneered in the development of orthopaedic surgery in that region and continued to work untiringly in this field.

Arthur Davis was born in Sebring, Ontario, in 1887, and his family moved to Buffalo in 1896. He was educated at the University of Buffalo, receiving his bachelor's degree in 1907 and his doctorate of medicine in 1913. He became interested in orthopaedic surgery while serving in the United States Army during the First World War. After his discharge from the Army, he spent eighteen months in Boston at the Massachusetts General and Children's Hospitals, furthering his training in this specialty. He then began the practice of orthopaedic surgery in Erie, Pennsylvania; and, by industry and ability, rapidly established himself as a leader in the community, both as a surgeon and as a citizen.

Relatively soon after beginning practice, Dr. Davis became interested in compression fractures of the spine. In spite of his remoteness from a suitable laboratory, he studied anatomical material and determined that, in these injuries, the anterior longitudinal ligament remains intact and is an unusually strong structure. He then reasoned that the deformity in compression fractures of the spine could be corrected with safety by gently manipulating the spine in hyperextension. A method embodying the principles of manipulation, combined with traction, was devised and applied to patients with compression fractures of the spine. The results were surprisingly good, and a description of the method and of cases illustrating the results obtained by its use was submitted to The American Orthopaedic Association as a thesis in 1928. The work * was accepted immediately and has revolutionized our treatment of these fractures.

Also in the 1920's, Dr. Davis conducted experiments upon the irradiation of milk with ultraviolet light, in an effort to prevent rickets. The completion of Steenbock's work on Vitamin D made this unnecessary. He also contributed to our knowledge of the treatment of fractures, especially those of the leg, in which he used the fibula to aid repair of the tibia. When the treatment of fractures by reduction machines and external skeletal fixation was receiving undue emphasis, Arthur Davis presented a series of cases in which union had been delayed or prevented by the distraction which is so easily obtained and maintained by this method, and offered a theoretical explanation of the mechanism by which the ill effects were produced. Always a keen student of the surgery of trauma, he was one of the foremost exponents of the pressure dressing, combined with immobilization, in the treatment of compound fractures, and presented brilliant results in a series of cases treated by his method.

Dr. Davis was greatly interested in research and often spoke with envy of those whose lot was cast in an environment where opportunity to study and adequate laboratory facilities were available. However, it is possible that, had such been his lot, the world would have been the poorer. His forte was clinical research and the treatment of patients.

His life might well be an inspiration to men who practise in localities remote from medical centers. Under such circumstances, Dr. Davis worked untiringly and enthusiastically for twenty-six years; and throughout this period he continued to contribute to our knowledge and remained an important figure in American orthopaedic surgery. A dreamer of dreams, a poser of questions about the universe, and a good companion, he will long be missed by his community, his friends, and his wife and four children. His work will live. Truly, it may be said of him that "the greatest reward for hard work is the ability to do more and better work".

* Fractures of the Spine. J. Bone and Joint Surg., **11:** 133–156 (Jan.) 1929.

Book Reviews

PHYSIOLOGY OF MOTION. DEMONSTRATED BY MEANS OF ELECTRICAL STIMULATION AND CLINICAL OBSERVATION AND APPLIED TO THE STUDY OF PARALYSIS AND DEFORMITIES. Dr. G. B. Duchenne. Translated and Edited by Emanuel B. Kaplan, M.D. Philadelphia, J. B. Lippincott Company, 1949.

This book, which originally appeared in 1867, represented the results of more than twenty years of investigation on the physiology of motion in man. The first idea of the author was to determine by electromuscular experimentation and clinical observation the proper actions which muscles produce, their mechanism, and the sources which contribute to the normal position of extremities during rest. By localized faradization of individual muscles, he intended to confirm the observations of the older anatomists, who had devoted so much study to the anatomy and physiology of muscles.

Duchenne's early experiments convinced him that this localized faradization was insufficient to give an accurate understanding of the physiology of voluntary motion. He came to realize that clinical observations of the action of individual muscles in relation to others of the group, both in normal and abnormal conditions, were necessary in order to understand physiological synergy of muscles. This led to the study of many patients with generalized and incomplete paralyses, special interest being in the patient with very limited paralysis.

By such observations, Duchenne came to understand the function of the individual muscles and their relation to one another; also the compensation provided when even one was atrophied or paralyzed. Without the exact knowledge of these facts, it was impossible to explain the mechanism of many deformities and distortions, and to determine the treatment indicated. Convinced of the importance of his findings, Duchenne undertook the writing of his book as a contribution to the solution of this physiological problem.

The first two parts of the book are devoted to the study of motion of the upper and lower extremities. The third part explains the respiratory movements and movements of the craniovertebral column, with an appendix which discusses the relation of sight to voluntary motion. A supplement, added at the request of the publisher, deals with motion of the face.

Valuable as Duchenne's book is, it has not been generally read by surgeons of the English-speaking world, because its treasures were hidden in a difficult French style, and the old French nomenclature differs completely from the nomenclature adopted by modern English and American anatomists. Dr. Kaplan has rendered a great service to the profession in making available in English this valuable classic. Few will appreciate the magnitude of his task; but, because of its accomplishment, many will be able to study Duchenne's investigations and conclusions. The book will be of real value to the anatomist, the orthopaedic surgeon, the neurologist, and all who are interested in the problems of rehabilitation.

The illustrations are line drawings reproduced from the original text. Quite suitably, the type used in the book is a type face of French origin. The book is beautifully printed and bound, a credit to the publishers who have undertaken this work.

LA LUSSAZIONE CONGENITA DELL'ANCA. NUOVI CRITERI DIAGNOSTICI E PROFILATTICO-CORRETTIVI. Marino Ortolani, Bologna, Cappelli Editore, 1948. 1,500 lire.

The secret of success in the treatment of congenital dislocations of the hip is early diagnosis. To this end, many different tests have been devised. In the main, these tests are based upon roentgenographic criteria and disclose anatomical variations from the normal which are suggestive of a congenital dislocation. Generally speaking, these tests cannot be depended upon during the first three months of extra-uterine life. It is precisely during this period that what the author calls the "*segno dello scatto*"—which may be freely translated as the "jump" sign—is especially valuable and is, in fact, pathognomonic.

The "jump" sign is elicited with the infant supine. The lower extremities are fixed upon the pelvis and held in a position of slight adduction and internal rotation. The extremities are then slowly abducted and externally rotated. As the femoral head mounts the barrier of the glenoidal labrum, escaping from the acetabulum, a characteristic jump can be felt and sometimes heard. This is similar to the manoeuvre which was formerly recommended as a test for the stability of closed reductions of congenital dislocations.

The first portion of this excellent monograph is devoted to a careful study of the anatomical basis of the "jump" sign. This is accomplished by careful arthrograms, roentgenograms, and anatomical dissections. The latter part of the work is given over to a description of the method of treatment by flexion and wide abduction, without immobilization in plaster.

This is a valuable contribution and would well merit translation into the English language. It is profusely illustrated with photographs of roentgenographic reproductions and anatomical dissections.

RECENT ADVANCES IN SURGERY. Ed. 3. Harold C. Edwards, C.B.E., M.S., F.R.C.S. London, J. and A. Churchill, 24 shillings; Philadelphia, The Blakiston Company, 1948. $6.50.

This volume, the first two editions of which were edited by Sir Heneage Ogilvie and published in 1928 and 1929, is an attempt to show current surgical practices to the returned war surgeon or his confrere who has been unable to keep up with contemporary surgical literature. It is necessarily sketchy as regards detail, but the bibliography is adequate.

It is divided into seven parts: General, which includes wound healing, shock, burns, water balance, et cetera; the Alimentary Tract, which also deals with the pancreas and spleen, but not the gall bladder; the Blood Vessels; and the Ductless Glands. All of these sections were written by the Editor. A section on the Thorax, by R. C. Brock, discusses surgery of the heart and bronchial carcinoma. D. W. C. Northfield has contributed a section on the Nervous System which is rather more inclusive and detailed than the rest of the volume. The final part is on Radiotherapy in Malignant Disease by Sir Stanford Cade; in this section the methods for treating each type of malignant disease are outlined.

As the Editor states in the Preface, many subjects have been omitted and the reports on some had become outdated by the time the page proofs were read. On the whole, however, this volume represents a reasonably complete survey of the developments in surgery during the past few years. The writing is simple, clear, and eminently readable. The authors' opinions are constantly expressed in controversial matters. For the surgeon who has fallen behind in his reading of current surgical literature and for the physician who wants to know what new surgical procedures may benefit his patient, this volume will be of value.

BACTERIAL AND MYCOTIC INFECTIONS OF MAN. René J. Dubos, Ph.D., Editor. Philadelphia, J. B. Lippincott Company, 1948. $5.00.

In his Preface, Dr. Dubos states that this book is intended to present "some knowledge of the bacteria, actinomycetes and molds pathogenic for man, as well as of the phenomena which characterize the infectious process". Included are the fundamentals of bacteriology,—the morphology and physiology of the bacteria and their pathogenic properties, as well as a discussion of immunity, allergy, and epidemiology.

The book deals with those relationships of parasite and host which concern the infectious diseases. The largest portion is devoted to a discussion of bacterial and mycotic groups. The disease or diseases caused by a parasitic agent are considered, and their treatment is outlined. Each chapter has been written by an authoritative worker in the field, and thus each subject is treated as an entity. Although this method of presentation fails to correlate the various diseases one with another, it makes the book of more value for reference.

An obvious lack in a book such as this would appear to be any mention of the virus or rickettsial diseases, but the omission was intentional. These agents are being discussed in a separate volume.

This work has been prepared from a practical rather than a theoretical point of view, and definite laboratory methods are set forth. It was written primarily for medical students, but will have interest for the general practitioner, as he comes in contact with the problems of infection. Each chapter contains a bibliography with references to recent publications by other workers. The whole subject has been presented clearly and concisely, and represents a valuable contribution to the bacteriological literature.

BRITISH SURGICAL PRACTICE. Volume 3. Edited by Sir Ernest Rock Carling, F.R.C.S., F.R.C.P., and J. Paterson Ross, M.S., F.R.C.S. London, Butterworth and Company, Ltd., 60 shillings (25 pounds for the set); St. Louis, C. V. Mosby Company, 1948. $15.00 ($125.00 for the set).

The third volume of *British Surgical Practice*, recently issued, is of special interest to *Journal* readers, because of the sections which happen to be included in this alphabetical division. Most important of these is "Deformities", prepared by H. Osmond-Clarke, F.R.C.S., of the London Hospital. The various types of congenital and acquired deformities are clearly and concisely presented, with the etiology, clinical picture, differential diagnosis, and treatment, most of them illustrated with excellent photographs, drawings, or roentgenograms.

Other chapters of value to the orthopaedic surgeon are "Contractures", by L. W. Plewes, M.D., Luton and Dunstable Hospital; "Cervical Rib and the Scalenus Syndrome", by Lambert Rogers, F.R.C.S., Royal Infirmary, Cardiff; "Diseases of Epiphyses", by H. E. Harding, F.R.C.S., Westminster Hospital, London; and "Chordoma", by Harvey Jackson, F.R.C.S., St. Thomas's Hospital, London.

The present volume is additional evidence of the great value of this series to the surgeon.

BRITISH SURGICAL PRACTICE. Volume 4. Edited by Sir Ernest Rock Carling, F.R.C.S., F.R.C.P., and J. Paterson Ross, M.S., F.R.C.S. London, Butterworth and Company, Ltd., 60 shillings (25 pounds for the set); St. Louis, C. V. Mosby Company, 1948. $15.00 ($125.00 for the set).

This book, another in the excellent series dealing with conditions usually treated by surgical techniques, follows the same plan as the earlier volumes, the material being classified under definition and etiology,

clinical picture, differential diagnosis, treatment, results, and prognosis. Of special interest to *Journal* readers are the chapters on: "Fascial Grafts", by W. Edward Gallie, M.D., of the University of Toronto; "Surgery of the Foot", by T. T. Stamm, F.R.C.S., of Guy's Hospital, London; "Fractures, Dislocations, Fracture-Dislocations and Allied Injuries", by F. W. Holdsworth, F.R.C.S., of Sheffield; "Gunshot Wounds and Allied Injuries", by C. G. Rob, F.R.C.S., of St. Thomas's Hospital, London; "Hand", by J. N. Barron, F.R.C.S. Ed., of Park Prewett Hospital, Basingstoke; and "Facio-Maxillary Injuries and Deformities", by Rainsford Mowlem, F.R.C.S., of Middlesex Hospital, London, and Hill End Hospital, St. Albans, and B. W. Fickling, F.R.C.S., of Hill End Hospital, St. Albans.

The series is a valuable one; the material carefully prepared, well illustrated, and attractively presented.

CAMPBELL'S OPERATIVE ORTHOPEDICS. Ed. 2. Edited by J. S. Speed, M.D., and Hugh Smith, M.D. St. Louis, C. V. Mosby Company, 1949. $30.00.

In the first edition of "Operative Orthopedics", prepared in 1939 by Willis C. Campbell and his associates, the purpose was to present to the experienced orthopaedic surgeon the various procedures which might be used in treating a given condition; the operation of choice was usually indicated and the reasons therefor.

The second edition of this work has been prepared primarily for a somewhat different reader,—the less experienced surgeon, well educated in the principles of orthopaedic surgery, but less able to make the wise decision as to the procedure indicated in the individual case. For the convenience of this audience, preliminary data have been added, which Dr. Campbell would have considered already well understood by the colleagues whom he had in mind as he outlined the material for his book. Because of this different point of view, much of the text of the original edition has been omitted and a great deal of new material added.

The development of new techniques in the last ten years has called for the inclusion of much new material, offering a wider choice of procedure for the surgeon. Careful attention has been given to the preliminary data necessary for the understanding of the use of the various procedures, as well as to postoperative care, so important for the maximum benefit from a given operation.

In the presentation of this new material, many new illustrations have been used, taken largely from the journals in which the various operations or refinements have been first presented by the individual surgeons, to whom credit is given.

Three new chapters have been added: "Preoperative and Postoperative Care"; "Amputations", written by Dr. Donald B. Slocum, formerly associated with Dr. Campbell; and "Peripheral Nerve Injuries", written by Dr. Francis Murphey, Associate Director of Neurosurgery at the University of Tennessee. A new section on "Rupture of Lumbar Discs", also written by Dr. Murphey, has been added to the chapter on "Miscellaneous Affections of Joints". The new section, "Mold Arthroplasty of the Hip", added to the chapter on "Arthroplasty", was written by Dr. M. N. Smith-Petersen of the Massachusetts General Hospital. Dr. R. A. Knight, who wrote the chapter on "Miscellaneous Affections of the Nervous System", was associated with Dr. Winthrop M. Phelps for one year and acknowledges his help in this field; Dr. Phelps reviewed the section on "Cerebral Palsy".

All of the other authors who have contributed to this extensive work are members of the staff of the Campbell Clinic. Dr. Speed and Dr. Smith, the Editors, collaborated with Dr. Campbell in the preparation of the first edition. Certainly Dr. Campbell's associates have honored him in compiling this more complete edition of "Operative Orthopedics".

The first edition has been recognized as an invaluable reference book for all working in the field of orthopaedic surgery; the new edition will be of even greater value to the younger and less experienced operator. The Editors and the publishers may well be proud of this contribution to orthopaedic literature.

PLASTER OF PARIS TECHNIC. Ed. 2. Edwin O. Geckeler, M.D. Baltimore, The Williams and Wilkins Company, 1948. $3.00.

It is an art to use plaster-of-Paris skillfully. Like other arts, perfection comes only through practice, directed along correct lines. In this little volume the author has stressed the accepted method, not only by text, but by carefully chosen illustrations. The incorrect method, in certain instances, is depicted by the resulting glaring mistakes.

Plaster fixation for various conditions involving any part of the body is considered in a systematic anatomical fashion, starting with the occiput and proceeding by way of the vertebral column to each extremity. Two chapters are devoted to plaster technique in war surgery. The author has included a chapter on "Follow-up Care" which goes beyond the actual use of plaster-of-Paris.

This monograph might well be a part of the plaster-room equipment.

THE MEDICAL ANNUAL. A YEAR BOOK OF TREATMENT AND PRACTITIONER'S INDEX. Editors: Sir Henry Tidy, K.B.E., M.A., M.D. (Oxon.), F.R.C.P., and A. Rendle Short, M.D., B.S., B.Sc., F.R.C.S. Bristol, England, John Wright and Sons, Ltd., 1948.

The *Medical Annual* for 1948 represents the sixty-sixth year of publication of this compilation of the

current developments in medicine and surgery in Great Britain. The format is essentially unchanged; brief discussions are included of medical topics, arranged alphabetically, followed by lists of recent pharmaceutical preparations and appliances, and of British and American books published during the year.

Little in the most recent issue pertains directly to orthopaedic surgery, but an interesting discussion of epiphyseal disorders, including dysplasia epiphysialis multiplex and premature cessation of epiphyseal growth about the knee joint, is presented by T. P. McMurray, Emeritus Professor of Orthopaedic Surgery of the University of Liverpool. Mr. McMurray also deals with the relation of the pyriformis syndrome to sciatic pain. "The term pyriformis syndrome is applied to that type of sciatica which is due to abnormal conditions of the pyriformis muscle, which are invariably traumatic in origin."

The subject matter of the *Annual* is comprehensive and, with its excellent index, the book is especially useful for reference.

TEXTBOOK OF CHIROPODY. Margaret J. McKenzie Swanson, B.Litt., F.Ch.S. Edinburgh, E. and S. Livingstone, Ltd., 20 shillings; Baltimore, The Williams and Wilkins Company, 1948. $5.00.

This is a short treatise, written primarily for students of chiropody; still, it contains many practical aids which may be of value to anyone interested in foot problems. The book includes definitions of pathological foot conditions, exceptionally well illustrated, followed by a description of the type of treatment a chiropodist is equipped to give.

The author is to be congratulated on giving us a well-written, concise monograph on the diagnosis and treatment of foot ailments.

FRACTURES AND DISLOCATIONS FOR PRACTITIONERS. Ed. 4. Edwin O. Geckeler, M.D. Baltimore, The Williams and Wilkins Company, 1948. $5.00.

The worth of a book which has warranted four editions in less than eleven years is almost self-evident. The latest edition of Dr. Geckeler's text contains no extensive changes over the preceding edition, but recent developments in traumatic surgery, many of them the result of experience gained in World War II, are included. About twenty illustrations have been added.

The subject matter is presented simply and concisely, and the text is well illustrated. Discussion of both immediate and follow-up treatment is included. The author states: "Emphasis has been placed on fundamentals for the student, and only the most practical methods have been selected for guidance of the practitioner". As a dependable, common-sense guide to present-day methods of treating fractures and dislocations, this book has proved of value.

POLIO AND ITS PROBLEMS. Roland H. Berg. Philadelphia, J. B. Lippincott Company, 1948. $3.00.

Mr. Berg has traced the experimental work which has been done on poliomyelitis during the present century, with comments on some of the larger epidemics of the disease. Particular mention is made of the contributing role of the National Foundation for Infantile Paralysis. An interesting discussion of the Kenny method is presented, with the statement that the percentages of mortality and of residual paralysis following the Kenny treatment closely approximate those observed by physicians using other methods.

The book is obviously written for the layman rather than the scientific worker.

COLLATERAL CIRCULATION (ANATOMICAL ASPECTS). Daniel P. Quiring, Ph.D. Philadelphia, Lea and Febiger, 1949. $5.00.

This small book describes the chief arterial and venous collateral channels of the body. The author states: "The term 'collateral circulation' denotes the subsidiary vascular channels, everywhere present in the circulatory network, which are a secondary line of defense against vascular breakdown. These channels transport the blood with varying degrees of effectiveness when the main channels become occluded or interrupted." The factors which are considered as determining the establishment of collateral circulation are outlined, and are fundamentally those set forth in 1924 by Spalteholz.

Much of the description is given by means of diagrams, many of them based on original dissections. After a brief discussion of the formation of capillary, arterial, and venous channels, the collateral circulation for the head and neck, trunk, heart, and extremities is considered.

Dr. Quiring, who is head of the Anatomy Division at the Cleveland Clinic Foundation, has not attempted to discuss fully such a broad subject. He has, however, provided a useful reference book; those who wish more specific information on circulatory problems may find his bibliography of value.

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Acta Chirurgica Belgica (Bruxelles), **40:** Nos. 4–9, Supplément 2, 1948.

Anales (Valencia, Spain), **3:** Núms. 1 y 2, 1948.

Anales de Ortopedia y Traumatologia (Montevideo), **1:** Nos. 1 y 2, 1948.

Archiva Medica Belgica (Bruxelles), **3:** Fasc. 2–6, 1948.

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